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MAY, 1930

SCHOOL SCIENCE AND MATHEMATICS

FOUNDED BY C. E. LINEBARGER

A Journal for all SCIENCE AND MATHEMATICS TEACHERS

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Why delay science teaching until the secondary school period? Our progressive schools now start systematic science training when the child enters school.

CONTENTS *for* MAY, 1930

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WHY ATTEND SUMMER SCHOOL?

Agassiz's advice to young teachers was, "Never try to teach what you yourself do not know and know well. If your school board insists on your teaching anything and everything decline firmly to do so." This discloses the dilemma which confronts a host of teachers every September, especially those who are drafted into service for science teaching and who are conscious of the inadequacy of their foundation in science and their lack of skill in handling scientific equipment.

Disquieting indeed, to members of the teaching profession was the statement recently made by Professor Clyde R. Miller of Teachers College, Columbia University, to the effect that there is a marked decrease in demand for teachers and an increase in the number of students entering the profession which has resulted in so serious an overcrowding that there are four applicants for every available position. From all sections of the country there comes the insistent demand for teachers with a higher grade of scholarship and with a more thorough professional training. Teachers in service often hesitate to surrender a desirable position in order to return to college for further training. Many, originally untrained in science have gradually trained themselves by means of self-imposed study and experimentation or by contact with experienced teachers.

Of the many ways for development open to the ambitious teacher, the summer school deserves special consideration. The two-fold aim of a well-balanced course in summer school is to deal with individual deficiencies in the fundamentals of science as well as with teaching methods in the

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Of the many ways for development open to the ambitious teacher, the summer school deserves special consideration. The two-fold aim of a well-balanced course in summer school is to deal with individual deficiencies in the fundamentals of science as well as with teaching methods in the

subject. A study is usually made of recent developments in both the theoretical and practical aspects of science and a careful examination is made of new text and reference books, new apparatus and new methods for presenting difficult topics. Most stimulating of all, perhaps, is the contact which one establishes with instructors and with other teachers taking the course who frequently hold very divergent views. It is by such discussions that one gains perspective in order that he may better evaluate the content of a science course and improve the technique of his teaching.

The extent to which the summer school fulfils its own objectives may best be learned from the following letters, contributed by teachers who have recently taken summer courses in various colleges:

Attendance at a summer school is worth while for any teacher anxious to advance. If we start teaching immediately after taking the bachelor's degree, four summers can lead to a master's degree in Arts or Science and few teachers today can progress very far without an advanced degree. After a few years of experience we begin to realize our shortcomings and to see more clearly what further study will be of the greatest help to us.

The youngster graduating from college seldom finds himself in the job he had dreamed of two or three years before, and if he goes into teaching, he is not likely to be fully prepared to teach just the subjects required of him. Then a summer session of six weeks, at which are discussed the ideas of others in his line, is simply invaluable.

The teacher today who fails to see any value in a summer school course may be likened unto the foolish advertising agent who thinks he is so far ahead of all his competitors that he can ignore the "American Association of Advertising Agencies." In a decade or so the others, profiting by the ideas each member shares with the group will have left him in the discard.

There are, of course, several almost insurmountable obstacles in the way of the ambitious, in our line as well as any other. Most of us do not surmount them! For example, we always feel we are underpaid, and must earn more funds in the summer time, at a camp, hotel, or elsewhere. Some schools have special funds that teachers can tap for graduate study. If this is the one obstacle that keeps you out of summer school, see if you can't find such a fund!

If you have no financial worries, perhaps you prefer to study in Europe, or just travel over there. If you can afford it, by all means go, but not every summer! A combination of first hand knowledge of the world, great familiarity with one's subject, and knowing how other successful teachers teach that subject will certainly make any good teacher a better one.

MORRIS WISTAR WOOD,
Westtown School, Westtown, Pa.

There is an old saying, "It is easier to get a cupful of water from a jar that is full of water, than from a jar that has only a cupful in it." Does not this apply to science teachers and summer school? Science is characterized by a very large body of quite definite subject-matter that is being increased rapidly. It is a life work to become expert in one field of science. The science teacher needs to be somewhat expert in several science subjects, or the science understanding of the high school students will be limited because of the limited understanding of the instructor. Is it not true that the successful teacher is the growing teacher? Is not the growing teacher alert, enthusiastic, full of his subject, and eager to adapt his methods to the student and community environment? Enthusiasm for usually comes with understanding of.

Summer school offers opportunities for the growing teacher. First, it offers the opportunity for taking advanced work for a higher degree. If the teacher is going to grow into a better position the higher degree will be necessary. This has been especially true in the last few years and will be more true in the future. Second, summer school offers stimulating contacts with other science teachers and makes for a better professional consciousness. Third, summer school offers inspirational contacts with former instructors. These contacts have much to do with the success of the beginning teacher.

Summer school, then, offers the growing teacher the opportunity of being the "full jar."

ERNEST ARMSTRONG,
Cozad, Nebraska.

For my first degree I majored in Education. After graduation I began teaching in high school. I became interested in science and in 1924 attended summer school. Among other subjects, I enrolled in "Teaching High School Sciences." I have never met a man who was more capable of inspiring students than the instructor in that course. He was full of energy, had a never tiring willingness to help students, and a well rounded knowledge of his subject. He very largely decided my future. I thought if a man can get as much pleasure out of studying science as he does in teaching it, science is the place for me. I may be the exception but he literally set me on fire. He gave me a burning knowledge for science. As far as I was concerned all else was secondary. He was the one teacher who left an idelible impression with me. Hence I would say that the value of a summer school is in direct proportion to the kind of teachers holding it.

A. M. EWING,
Division of Freshman Chemistry, Ohio Northern University, Ada, Ohio.

Last summer was one of the most enjoyable and instructive that I have had for some time. As an aid to my teaching, I enrolled in course entitled "The Teaching of High School Physics." This proved to be a very valuable course and I feel that my presentation of the subject this year is a great deal better than last year. I also took a course in the "Appreciation of Music." This course was most enjoyable and I consider that my time was very well spent.

KENNETH L. GODING,
Amherst High School, Amherst, Mass.

It seems to me that Summer School is exceedingly worth the investment of time and money; first, because it gives a teacher, old or young, a unique opportunity to integrate new knowledge and technique with experience, and because it makes it possible to dispel one's mind of illusions in the theory of education, and open up more to the real facts. I personally found the contacts and the opportunities to talk over the different sides of teaching, made it all as worthwhile as the chance to pick up whatever subject matter I happened to need. I hope to be able to spend some time about every other summer at some summer school; as I look at it now, this is not only desirable, but I should say, quite necessary.

J. B. WHITELAW,
Brooks School, North Andover, Mass.

From my experience and observations I have decided that summer school is one of the most effective agencies for stimulating *growth* in a science teacher.

1. Gains in the field of scientific knowledge are so rapid and far-reaching that it is imperative for the progressive science teacher to attend summer school in order that he may keep informed concerning this development.
2. Reward for acquisition of this knowledge comes in the ability to do better work which produces satisfaction and leads to promotion.
3. Opportunity is offered the teacher of limited means to finance further study by teaching in winter and by attending in summer a school where laboratories are well equipped, and courses may be had under highly trained instructors.
4. Wants pertaining to difficulties that have appeared during the teaching experience, may be satisfied by the information given by experts in the scientific field who have anticipated these problems and offer suggestions for their solution.
5. Time may be saved by utilizing the vacation season for the broadening and enrichment of life through professional contacts and through the general acquisition of knowledge.
6. Happiness prevails in the well organized summer school where recreative and social activities eliminate the irksomeness of daily program.

EDNA C. DRUMMOND,
Nashville, Tenn.

WHAT THE COMMON SCHOOLS HAVE HELPED AMERICA TO ACHIEVE.

1. Rapid rise to national greatness.
2. Realization of democratic ideals.
3. Quick conquest of a vast frontier.
4. Widened opportunity for new citizens from overseas.
5. The highest place ever accorded women.
6. The ability to create, manage, and staff efficiently, large scale production.
7. The noblest standard of living ever realized over a large area.
8. The highest level of intellectual life ever attained by the common people.
9. Steady improvement in the art of selfgovernment.
10. Appreciation of the significance of childhood and the home life.

A FEW NOTES ON COLLOIDS.

By W. C. Hawthorne,
Crane Junior College, Chicago, Ill.

References: (1) Findlay, Chemistry in the Service of Man; (2) Duncan, Some Chemical Problems of Today; (3) Duncan, Chemistry of Commerce; (4) Bayliss, Physiology. (5) Burns, Introduction to Bio-Physics.

The first classification of material made by any science is into two grand divisions: Things that can be studied, and things that may not, or cannot be studied. Thus chemists divided the multitude of things that came to their attention into crystalloids and "messes." It is not surprising that the former were the only solids studied by them for a hundred and fifty years from the beginning of the science, for their manipulation is easy; they are either soluble, giving a clear liquid which runs through a filter paper, or they are insoluble and are left on the filter paper, to be dissolved in some other reagent. Thus they are easily purified, and easily recognized.

But there are several classes of substances that refuse to play the game;—perhaps we should say today that any substance under certain conditions may refuse to play the game. Some of these you have met in the laboratory: (1) muddy suspensions of As_2S_3, Sb_2S_3, $CaSO_4$, gelatinous hydroxides, etc., that neither remain behind on the filter paper nor settle out to leave a clear supernatant liquid. Then there are substances (2) like egg albumen, soluble in water but not passing through membranes that allow crystalline substances in solution to pass quite readily. Or again, there are such substances as glue (3), a solid, but with no evident crystalline structure. It is soluble, but it does not dissolve as a crystal of $CuSO_4$ dissolves. Drop a large crystal of the latter into water, and in a short time, the deepening blue of the water will show that solution has begun, while the crystal has become smaller. Examination will show that apparently a few layers of molecules have been, as it were, shaved off each face of the crystal. Nothing of the sort happens in the case of a lump of glue in water. It simply absorbs water and swells, and when, after half an hour or so, it is removed, the remaining water may show hardly a trace of the glue. But in time the glue has

absorbed all of the water, and if there is enough of the latter, we have an apparent solution.

The first man to make a scientific study of these "messes" was Graham, from about 1855 to 1865. He found a large class like these last mentioned, and from their resemblance to glue gave them the name "colloids." He believed that their distinguishing trait was their inability to pass through parchment paper. But other substances not at all "glue-like" were soon recognized as having the same property. Farady had rediscovered the "potable gold" of the alchemists, a clear, ruby-red liquid obtained by reducing $AuCl_3$ by tannin. A blue liquid may be obtained by treating $AuCl_3$ with hydrazine as a reducing agent. These look like perfectly clear solutions, but the use of the ultra-microscope reveals the presence of particles enormously larger than molecules. The color depends upon the size of the particles. Colloidal suspensions of platinum and of other metals may be prepared by using the metals as terminals of an electric arc under water; colloidal $Fe(OH)_3$, by the dialysis of a perfectly neutral solution of $FeCl_3$, whereby all the crystalloid substances in the solution pass through a semi-permeable membrane, and are eliminated. Insoluble solids may be ground so finely that the powder will remain in suspension indefinitely. In fact, it is now considered that any substance may be, by the proper methods, brought into the colloidal state, and suspended in a liquid in which it is insoluble. Thus, even common salt may be prepared as a colloid in benzine. In view of these facts, we now speak not of colloids, but of the colloidal state of matter, and consider that the only difference between a solution and a suspension is in the size of the particles. If the particles are of molecular dimensions, it is a solution; if large enough to give the "Tyndall Test" (really devised by Faraday), an undoubted colloid. This test is the appearance of at least a haziness in the cone of light in an ultra-microscope. But the smallest particle that will give this test doubtless contains hundreds, if not thousands, of molecules. What about the solutions (suspensions?) of particles of intermediate sizes?

Or again, take Graham's criterion, the passing or the

failing to pass through a semi-permeable membrane. But this depends upon the particular membrane and the particular substance. Some membranes hold back certain colloids, while allowing others to pass. Most membranes hold back haemaglobin, though it is undoubtedly in the molecular condition, but the molecules are very large. On the other hand, colloidal gold has been prepared with particles as small as 6 mm in diameter. When we remember that the starch molecule is probably 5 mm and the CO_2 molecule as much as 0.3 mm in diameter, we see that some colloidal suspensions are pretty close to molecular solutions. So we have ceased trying to distinguish sharply between them, and the words solution, solvent and solute no longer have the definite meanings that scientific terms should have. Instead, we speak of a mixture as having two phases,—the external or continuous phase, and the internal or dispersed phase. Evidently these terms may be used in speaking of suspensions or of true solutions indifferently.

For the sake of completeness, we may enumerate various classes of mixtures, all of which show the characteristic colloidal behavior to a greater or less extent:

External or continuous phase	Internal or dispersed phase	Examples
(1) Gas	Solid	Smoke
(2) Gas	Liquid	Fog, mist, spray
(3) Liquid	Gas	Foam, suds, lather
(4) Liquid	An immiscible liquid	Milk, lymph, raw egg-white
(5) Liquid	Solid	Colloidal suspensions
(6) Solid	Liquid	Jelly
(7) Solid	Solid	Cast iron, alloys, ruby glass

To the physiologists, Nos. 4, 5 and 6 are the only ones of importance. Nos. 4 and 5 are known as sols,—hydrosols, alcosols, glycerosols, etc., according to the nature of the medium. Samples of No. 6 are frequently referred to as hydrogels, etc. Members of class No. 4 are also spoken of as emulsoids; those of No. 5 as suspensoids.

It is sometimes difficult to distinguish these classes, which shade into each other. Thus, milk contains suspended solids, as well as being an emulsion of butterfat and protein material. Often the internal phase is nothing but a more concentrated or less concentrated solution of the same materials as are found in the external phase.

Heating may liquefy the solid phase, so that a No. 6 or a No. 5 may pass into a No. 4, as is the case with ordinary gelatine. This process is reversible. But we may have irreversible changes, as when heat coagulates the albumen in a solution of egg-white. In this case, a No. 4 passes into a No. 5 or a No. 6, depending on how much water may be present. It is surprising, however, how much water may be held in a gel,—sometimes as much as 99 per cent of the total mass. But it must be pointed out that this water, dispersed as it is in minute droplets, must be subjected to such immense pressure due to the surface tension that it may well lose much of its fluidity. Reinke found that dried laminaria under a pressure of 42 atmospheres was still able to absorb 16 per cent of water. That there is an actual diminution of volume may be seen by attaching a few shreds of this dried sea-weed to the bulb of a hydrometer and floating it in water. As water is absorbed, the hydrometer sinks (4, p. 100).

All these different classes mentioned above except number 7, are roughly characterized, as has been suggested, by the ability to pass through filter-paper (since the particles are too small to be retained) but not through semi-permeable membranes (particles too large), although this depends somewhat upon the particular membrane and the particular colloid; and by a very small osmotic pressure, since the particles are few in number. It was for a long time thought that osmotic pressure was entirely lacking, but more refined measurements gave positive results.

It is a further peculiarity that many colloids possess an electric charge. Acids, salts, sulphids, metals, clay, quartz, carbon and the like generally carry negative charges; metallic hydroxides and basic substances generally, positive charges; while albumen and gelatine are neutral. But the method of preparation generally determines the nature of the charge, and it may be altered almost at will by the proper treatment. Notice the difference between this kind of electrification and that found in electrolytes, where the charge is not only invariable as to kind and quantity, but where equal charges are always produced. Here all the particles migrate in the same direction in an electric field. This is called cataphoresis, and is made use

of in several commercial operations. Particles of smoke may be separated from the hot chimney gases by passing them between electrically charged plates; tannin may be driven into the hide and the tanning hastened; medical treatments have been devised depending on this operation; peat with too large a water content to be handled and dried by the ordinary processes is freed of its water content by this method in Germany. The small amount of electricity actually needed for these operations is quite astonishing (2, p. 122).

The possession of an electric charge explains the precipitation of many colloids by salts which can furnish an ion of the opposite sign. The precipitating power of the ion depends upon its valence, varying as the square for bivalent, and the cube for trivalent ions, as compared with the power of a univalent ion. Thus colloidal As_2S_3 with a negative charge is precipitated equally well by 6KCl, $3K_2SO_4$, or $2K_3PO_4$. But $CaCl_2$ has four times the effect and $LaCl_3$ nine times the effect if we take equimolecular quantities of each (4, p. 89). The smaller the particle, the greater the density of the charge, and the greater the quantity of neutralizing material needed to precipitate it (4, p. 94). But the size of the charge depends more upon the method of preparation, and may be increased or diminished by the addition of the proper salts. For precipitation, it needs only that the charge on the colloid be neutralized, and this may often be done by the addition of another colloid of the opposite sign. Thus, colloidal $Fe(OH)_3$ will precipate colloidal As_2S_3. It is probable that those usually crystalline substances are kept in the colloidal state by the presence of electric charges on the small particles. When these are neutralized the particles agglomerate and come down. On the other hand, removal of the precipitating material, which is brought down with the colloid, as by washing on the filter paper, may reconvert the coagulated material into the smaller, apparently dissolved particles. It is for this reason that some precipitates must be washed with a salt solution, such as ammonium nitrate. The reconversion of a coagulated substance into a suspension is called peptization.

It is sometimes hard to tell just what part adsorption

plays in this process of precipitation. It may be that whether the oppositely charged ion shall be taken up, thus neutralizing the charge, or the similarly charged ion attracted, thus increasing the charge, depends primarily upon the preferential power of the surface of the colloid to adsorb certain substances, irrespective of the charge they carry. Many dyeing operations depend upon this adsorbing power. The dye is first absorbed on the surface of the material along with whatever charge the dye carries. The mordant must be something that carries an opposite charge. When this is adsorbed, the charge is neutralized, the particles agglomerate in situ, and cannot thereafter be removed. Neutral or non-colloidal dyes are not thus affected, of course.

The clarity of sea-water, as compared with that of lakes and rivers, may be explained by this electrical precipitation. Much of the mud brought down by streams is in the colloidal state. Meeting and mixing with the salt water at the mouth of the river, the mud is precipitated and this accounts for the bars which are such a hindrance to navigation. Or we may compare the contents of the "Big Muddy" with the relatively clear waters of the Ohio, which come from a limestone region and are charged with calcium salts. The Missouri comes from the granite Rockies and holds little mineral matter in solution.

There is still another reason for the muddiness of some rivers. If they flow through cultivated regions, they have leached from the soil a great deal of humus, a light colloidal material, and this adsorbs a great deal of the finest particles of mud and they are held in suspension instead of uniting with each other to form larger particles which would precipitate.

The real influence of the humus upon the particles of clay was discovered by Acheson (2, p. 119) who tried to find out why certain German clays were so much more plastic than American clays, which had a tendency to become lumpy, and which shrank and warped on baking. He found first that the addition of minute amounts of sodium hydroxide would prevent this, and then that water in which straw had been steeped would have the same effect, and, remembering the trials of the Hebrews when commanded

to make "bricks without straw," he called his product "Egyptianized clay." The German clay had been mixed by nature with organic material. He finally concluded that tannic acid was the most effective material, and that the action was due to the colloidal material coating the particles of clay and preventing their coagulation. Next he treated with tannic acid a particularly fine unctuous graphite that he had prepared by grinding, and found that it could be suspended in water to make a permanent mixture, instead of one that had to be shaken up every time it was used. It was called "Acheson's deflocculated graphite,"—soon shortened to "aquadag" or "oil-dag" according to the dispersing material used. Either makes a very superior lubricant. Very soon a host of new industries was started, and pigments for paints, fillers for paper and rubber, etc., etc., prepared in the same way, were on the market.

The colloidal humus spoken of above is a valuable constituent of the soil just because of its colloidal characteristics, not because it a plant food in any sense of the word. It absorbs a great deal of water, thus preventing the rapid drying out of the soil, and adsorbs much plant food on its huge surface. This plant food consisting, as it does, of soluble salts, is rapidly washed away from soils wherein there is a deficiency of humus.

Altho the light colloid, humus, holds mud in suspension heavier colloids such as ferric hydroxide are used by the thousands of tons in clarifying many a city water supply. It adsorbs the mud particles, making a combination of sufficiently high specific gravity to settle rapidly, carrying down at the same time, so it is claimed, most of the pathogenic germs present (1, p. 214).

The relatively enormous extent of surface is one thing that makes the action of colloids so enormously effective (4, p. 79). A sphere one millimeter in radius has a surface of 0.126 square centimeters, while the surface of the same mass, reduced to colloidal dimensions, say ten millimicrons in radius (and even then it would probably contain over a thousand molecules) has a surface of one hundred square meters, or more than a million times as much as before with consequently a million times the adsorptive

power. It is easily seen how a small fraction of one percent of gelatine in a solution may prevent the precipitation of salts in analysis. This same adsorptive power becomes a most valuable property, however, in the preparation of many medicines. Thus, starch "solution" is said to "dissolve" many drugs insoluble in water; gelatine or albumen is used in the preparation of colloidal silver for influenza, colitis, and bacillary disentery; colloidal manganese is injected for acne; sulphur and iodine for rheumatism, etc. Not classifying soap as a medicine, its cleansing action may be mentioned here, nevertheless. It is probably due not only to its saponifying action (very slight) on the oil to which the dirt is adhering, and the lessening of the surface tension which enables the water to work its way under the dirt, but more perhaps to the adsorption of the dirt by the colloidal soap. (1)

In the arts, we find instances aplenty of the value of colloids. Many have already been mentioned. Photographic plates are prepared by precipiting AgBr in a solution of gelatine which adsorbs the salt, and so prevents the crystals from running together to form such large grains as would make the plate worthless. Gelatine in the ice-cream prevents the formation of large ice crystals, thus giving a smoother product. Perhaps also it prevents the aggregation of the droplets of butter-fat.

Another very prominent characteristic of colloids is their tendency to act as catalytic agents, and in this respect they are startlingly like those organic catalysts known as enzymes. For instance, (3, p. 24) one gram of colloidal platinum in 300,000,000 grams of water is wonderfully effective in decomposing hydrogen. But so, too, is the haemase of the blood, and the action is very similar. Too, both enzymes and colloids are "poisoned" or checked in their catalytic action by exactly the same substances, such as potassium cyanyde. Numerous examples similar to these are given by Duncan (2). It is possible that the catalytic action in both cases takes place at the surface of the colloid or the enzyme, where the forces of surface tension and adsorption are so active.

In spite of all the work done on colloids in the last twenty years by hundreds of investigators, no clearer statement

of their importance has ever been made than by Graham in 1861; "The colloid is, in fact, a dynamical state of matter, the crystalloidal being the statical condition. The colloid possesses ENERGY. It may be looked upon as the probable primary source of the force appearing in the phenomena of vitality."

THE MOST DESTRUCTIVE MAMMAL IN THE WORLD.

By CLARENCE L. HOLTZMAN, *Waller High School, Chicago.*

The common brown rat is so designated by David E. Lantz of the United States Biological Survey.

For this reason it was thought advisable to include this animal, together with a laboratory study of the white rat, in the work on mammals in year's course in Zoology.

The publications are, "Separate From Yearbook, Department of Agriculture, No. 725," obtainable from the Supt. of Documents for five cents each, and also the "Geographic Magazine of July, 1917." Each pupil is given a set of questions based on the bulletin and magazine—the purpose being not so much to get particular answers, as to insure a careful perusal of the article.

An estimate is also made of the possible number of rats produced in one year or two years from one pair and its descendants at the given rate of increase—the astonishing number readily explains why it is such a pest.

QUESTIONS.

The House Rat.

1. How does the proportion of people and rats compare in the U. S.?
2. Where is the rat harmful in the U. S.?
3. How can the rat be credited with more deaths than caused by the world war?
4. How did the U. S. escape disaster in 1908 and 1914?
5. What diseases do rats transmit?
6. How large an army of farmers would be necessary to raise food for the rats of the U. S.?
7. How many acres would be necessary to raise their food and pay for their damage done?
8. Why do rats love farms?
9. Why do rats migrate?
10. Why are rats and mice more abundant about the house in winter?
11. What are two reasons for man's failure to completely exterminate rats?
12. What are the four best methods of combating rats?
13. What dogs are good ratters?
14. How many rats and sparrows did the club in England get for thirty dollars bounty?
15. How did the black rats travel from Canton, China, to Baltimore?
16. What was the cost of rats in Baltimore in 1908?
17. What measures are advised to rid cities of rats?
18. How was the Bubonic Plague introduced into San Francisco?
19. What are some of the natural enemies of the rat?
20. What poisons are recommended for use in exterminating rats?

AN ANALYSIS OF BIOLOGICAL DRAWINGS.

BY AMER M. BALLEW,
Austin High School, Chicago, Illinois.

The process of drawing is much used as a form of laboratory procedure. The time consumed in the production of drawings reaches its maximum in the biological sciences where it often forms the major part of the laboratory procedure. It is not uncommon for teachers to require the students to color the drawings or to go over them with ink, using the laboratory period for this kind of work.

A critical comparison of the drawings of any class will demonstrate the fact that many students encounter great difficulty in making the required drawings. The student with artistic ability has a distinct advantage in the construction of biological drawings as they are usually required today; an advantage which is readily recognized by the other members of the class. It naturally follows that students come to regard the drawings as the ultimate objective of laboratory procedure and we find a strong tendency to copy drawings from the textbook or other students and often the tracing of drawings from reference books. The writer has had students enter his course from other schools. An inspection of their laboratory notebooks would often reveal drawings copied entirely from the textbook. Indeed, not infrequently it was possible to tell what text the student had been using in the other school by looking over two or three of his drawings. It need hardly be stated that such work was largely a waste of valuable laboratory time.

VALUES CLAIMED FOR DRAWINGS

The writer was recently privileged to make a rather intensive experimental study of drawings in high school zoology[1]. In the working out of this study it was necessary to analyze the values of drawings as stated by teachers and various writers on methods in high school biology. The values claimed for drawings may be stated as follows:

1. Drawing aids in the analysis of processes or of use of parts.

[1] Ballew, Amer M. A Comparative Study of the Effectiveness of Laboratory Exercises in High School Zoology With and Without Drawings. School Review, XXXVI (April 1928) 284-295.

2. Drawings aid the pupil in remembering things he has observed.
3. Drawings aid the pupil to see more things as he studies the specimen.
4. Concentrates attention on the object.
5. Aids in uncovering weaknesses in pupils' conception of important facts.
6. Necessitates repeated and accurate observations.
7. Fixes in mind the things observed.
8. Develops and increases one's ability to see more things and in greater detail.
9. Drawings are evidence of how much and how accurately a student observes.
10. Aids pupil to develop appreciation for form.

A study of these values would indicate that they can be reduced to two general types: (1) aids the pupil in making analytical observations and (2) aids the pupil in remembering observations.

Types of Drawings

Very little distinction is made at the present time in regard to different kinds of drawings used in biology. They are usually all referred to under the general term "drawings."

It would seem advisable to classify drawings into two groups, representative and analytical. They are distinctly different in their method of construction, processes involved on the part of the student and in the length of time required for their construction. The writer's experimental study was limited to representative drawings. Ayer[2] in his excellent treatise on drawings made extensive investigations of both types of drawings.

An example of a representative drawing is a drawing of a fish as seen from one side. The structures are all labelled. In this type the student attempts to make his drawing look as much like the specimen as possible.

The drawing of the cross section of an earthworm represents an analytical drawing. In this case the student does not attempt to make his drawing look like the specimen, but attempts to show the relative position of the various structures. The student must analyze the relation

[2] Ayer, Fred C. The Psychology of Drawing. Baltimore: Warwick & York, Inc., 1916. 180 p.

of the various parts of the specimen in order to make a satisfactory analytical drawing.

The representative type of drawing is much more widely used than the analytical. An examination of several laboratory manuals used in biology revealed the fact that approximately 85 per cent of the suggested drawings could be classified as "representative."

Processes Involved in Construction of Representative and Analytical Drawings

In the representative type of drawing, the student is chiefly concerned in making a pictorial representation of the specimen being studied. He desires to make his drawing resemble the specimen in general characteristics. The student is not primarily interested in a critical analysis of the material being observed, but will usually start drawing after giving a few hasty glances at the specimen. The student is quite apt to be more interested in the mechanical processes involved in drawing than he is in careful examination of the materials being studied. The process is somewhat analogous to that of photographing a bird. The individual is chiefly concerned with the adjustments of the camera and not in making accurate observations of the bird. In both cases a good picture is the objective.

A critical analysis of representative drawings will disclose many inaccuracies as far as detailed structure is concerned, although the time spent in constructing the drawings is usually considerable. Such a simple observation as counting the number of spines in the dorsal fin of a perch is often missed by the majority of the class.

The construction of representative drawings requires complicated motor and visual coordination. This type of coordination is closely associated with artistic ability. Experience shows that the correlation is not high between artistic ability as shown in representative drawings and an accurate understanding of the materials under study.

In the analytical type of drawing the student does not attempt to make his drawing look like the specimen but attempts to show the relative position of the various structures. The student must analyze the relation of the various parts of the specimen in order to make a satisfactory drawing. In the case of the earthworm the student

must know how many body layers are present; the relation of the body cavity to the alimentary canal; the relation of the principal blood vessels to the alimentary canal; the location of the chief nerve cords; and so on. Analysis is very definitely focused upon the specimen.

The analytical drawing itself is a very simple affair consisting, in the case of the earthworm, largely of a few circles of varying diameter. In contrast with the representative drawing, a maximum amount of time is spent in analyzing the relationship of structures and a minimum amount of time devoted to the diagrammatic record. This leaves the major portion of the laboratory period open for a critical study of the materials under observation.

The complicated visual, muscular type of coordination required in the artistic representative drawing is largely absent. The simplicity of the diagrams enable the instructor to quickly check the thoroughness of the students' analysis and to carry out remedial measures within the laboratory period.

Use of Analytical Diagrams in Directed Study

It is recognized today that secondary school students need guidance in the formation of proper study habits. In many schools part of the class period is devoted to this kind of work. Rightly interpreted, this means considerable more than telling the students to read the next few pages. Analytical diagrams fit very nicely into a program of directed study and yet their use does not seem to be widespread.

It is desirable after studying several typical types of invertebrate animals, that the student grasp the fundamental structures involved in the development of the nervous system in the various animals; the similarities and differences involved.

Dissection in high school biology is of doubtful value. Even the most optimistic would hardly advise the dissection of the nervous system of invertebrate animals. Diagrams in textbooks are usually vague concerning these structures if they are present at all. Most texts, however, give accurate descriptions of the nervous system. The following description of the nervous system of the crayfish is an illustration.

"The 'brain,' the supraoesophageal ganglion, of the crayfish is a mass of nervous tissue resulting from the aggregation of several pairs of ganglia. Pairs of nerves may be traced to the eyes, the antennae, and the antennules. Two slender connectives, similar to those described for the locust, extend from the brain, encircle the oesophagus, and join the suboesophageal ganglion posterior to the mouth. This ganglion, too, is really a combination of several pairs of ganglia, which send off the nerves to some of the head somites and to some of the thoracic somites. There are five other ganglia in the thorax joined to each other and to the six ganglia in the abdomen, by the double nerve-cord which is a continuation of the connectives that encircle the oesophagus."[3]

Fig. 1 illustrates the acceptable type of diagram constructed by those students who have read the description of the nervous system of the crayfish in a critical, analytical manner.

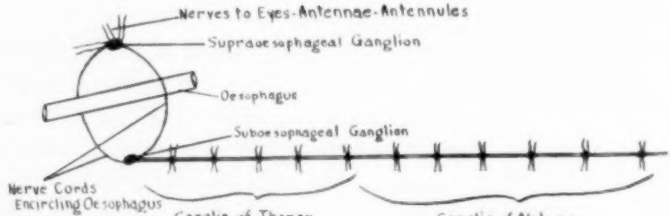


FIG. 1. ANALYTICAL DIAGRAM OF NERVOUS SYSTEM OF CRAYFISH CONSTRUCTED BY STUDENT AFTER CAREFUL STUDY OF DESCRIPTION IN TEXTBOOK.

As the instructor moves from desk to desk he can tell at a glance which students are encountering difficulty and at what point in the analysis their difficulty lies. Here is a student who has not caught the idea that the oesophagus is encircled by nerve cords; another, perhaps, has failed to show the proper number of ganglia in the abdomen. They must read again and perhaps look up certain words in the dictionary in order to get a clear conception of the description. Mistakes are corrected when they are made

[3] Linville, Henry R. and Kelly, Henry A. A. Textbook in General Zoology. New York: Ginn and Co., 1906. P. 134.

which is the psychological time and not after a lapse of several days when student enthusiasm has considerally died down.

If the instructor sees that the diagrams are honestly made and not copied, this type of work will be found quite profitable for the directed study period. It is much easier to prevent the copying of student diagrams in the study period than in the laboratory period when more freedom is ordinarily permitted. If diagrams of this sort are constructed for several different types of invertebrate animals, the student will get an intelligent idea of the general scheme in invertebrate nervous systems, which after all is about all that we can expect.

The question may be raised at this point: Why have the student construct a diagram if the textbook gives an adequate description of the structures involved?

In reply it should be noted that the analytical diagrams require a minimum of drawing. If the student merely reads the text the instructor has no way of knowing what difficulties are being encountered. By means of the diagram the difficulties of the entire class may be analyzed and remedied within the class period. The construction of diagrams by the students gives a visual aid to retention. Good study habits are developed. Reflective reading and critical analysis are demanded. The prevalent student opinion that studying consists of reading a definite number of pages through once breaks down here in a most decided manner. The instructor will notice an attitude of concentration on the part of the students which is ordinarily lacking in a mere reading of the text; motivation has been definitely established.

Recommendations

The reader has perhaps gotten the idea that the writer would advise making all of the analytical drawings from descriptive reading. Not at all. Observation based on actual material is always of primary importance. The construction of analytical drawings from textbook descriptions is only advocated as an effective tool for use in the directed study period and at times when observation of actual materials is impracticable.

Objective experimental data indicate that representative drawings do not aid the student in making analytical ob-

servations or in the retention of observations. The same data show that analytical drawings are valuable in securing analysis and retention. We still find students' notebooks largely filled with representative drawings. It would seem that the burden of proof is upon those who advocate the widespread use of this type of drawing. Mere opinions are of doubtful value. We must have experimental evidence. Methods are changing in practically every form of human activity as scientific investigation throws its light upon the subject. Methods in biology must be prepared to withstand similar investigation.

Many of our present day methods in biology have been directly handed down from the university. The university has emphasized morphology with its inherent representative drawings. High school teachers have, in many cases, bodily transplanted this method to secondary school biology. The time has passed when a high school course in biology consists simply of a somewhat simplified edition of a similar course in the university. Present day psychology and education have quite definitely shown that the objectives and methods at the secondary school level are quite distinct from those of the university level. Tradition and mental inertia have retarded the general recognition of these principles in biology.

It is a comparatively simple task to issue directions for representative drawings. They may be characterized by the following directions found in laboratory manuals: Make a large drawing of a fish as seen from one side and label all the structures. Perhaps the ease in giving directions for this type of drawing and the length of time it keeps the students busy is one factor influencing its common usage. What student of biology does not remember how be labored over the drawing of the crayfish and its many appendages?

On the other hand, if the analytical drawing is to train the student in making accurate observations it requires careful explanation and presentation on the part of the instructor. The comparatively short time required for the diagram leaves more time for the student to study the specimen. The student must be guided in making observations.

The instructor may effectively lead up to individual student observation by a brief, informal talk at the beginning of the laboratory period while the students have the specimens on their tables. Simple diagrams on the blackboard, the use of modeling clay and models may be used to good advantage. Students need to be trained in visualizing the appearance of structures when cut into various kinds of sections. This is absolutely essential for the proper working out of analytical diagrams.

After the instructor has made use of these aids, the students should then be made to clearly understand the type of diagram required. They should understand the simplicity of it and just what it is that they are to show. The instructor needs to guard against the tendency of telling the students too much and destroying their initiative and enthusiasm. It will probably be more effective to require all books to be closed when the diagrams are made in the laboratory. Diagrams should be checked within the laboratory period and corrections made at once.

It would seem advisable to omit representative drawings from the high school biology course. Let us shift the emphasis from the artistic, pictorial type of laboratory notebook to effective training in analytical observation. It is the function of the art room to develop artistic ability while training in observation and analysis rightly belong in the realm of the laboratory.

THE ELECTROSCOPE DEMONSTRATION.

Editor of SCHOOL SCIENCE AND MATHEMATICS:
Dear Sir:

I wish to take exception to Dr. Black's demonstration with the Electroscope described in the April number of the Journal. My objection is that, by causing the pupil to watch the shadow on the wall, his attention is drawn away from the experiment itself. I make the demonstration just as easily seen without incurring this difficulty. To do this I have replaced one of the clear glass plates of the Electroscope with a ground glass plate and, by placing a source of illumination back of the Electroscope, cast the shadow of the leaf on the ground glass. This gives a sharp black shadow of the leaf easily seen from any part of the lecture room and keeps the attention of the student at the point where the demonstration is being made. This is the advantage that I claim for my method. I am

Sincerely yours,

JOHN B. ESMAKER,
Instructor in Physics, St. Ignatius High School.

BACKGROUND AND FOREGROUND OF GENERAL SCIENCE.

No. XI. The Weather.

By Wm. T. Skilling,

State Teachers' College, San Diego, Calif.

More advanced studies of science are for the purpose of acquiring power over natural forces. General science is fulfilling a sufficiently important purpose if it helps pupils to take a more intelligent view of their natural surroundings thus adding zest, interest, and happiness to life. Common things of life become endowed with a new meaning. Thought is evoked where formerly the observer having eyes saw not, and having ears heard not.

The weather is one of those common-place factors in our environment which the general science teacher should seize upon to electrify into a thing of new interest. Pupils have already observed the facts about weather but facts are lifeless things without the reasons for them. They know that it rains, it snows, it is cold or hot, dry or moist, windy or still, clear or cloudy, but why it is so they cannot tell and do not often stop to consider.

As a starting point the class should be made to understand that the sun and the air are the two agencies responsible for all kinds and changes of weather. Without the sun or some equivalent source of heat this would be a very dead, inactive world. Air is stirred up by the sun's power to warm portions of it more than other portions and to evaporate water into it.

The use of comparison is a teaching device frequently useful. How would the weather on the moon, where there is no atmosphere, compare with that on the earth? Temperature changes there would be wholly due to differences in the amount of sunshine received at different times. Here a change in wind direction or air pressure may radically affect temperature. No rain, snow, or frost could form on the moon for lack of moisture. Our sea breezes make the climate near the ocean very different from that of a corresponding latitude inland. The moon has no seas. Temperature of lofty lunar mountains should be scarcely if at all different from that at low levels for such differences with us are caused by the relative amount of absorption of heat by air at different levels, and by the expansion or contraction of air as it either rises or descends.

Though meteorology is far from being an exact science there are many questions that a child would naturally ask for which science can give at least a partial answer. Why for example are

some days clear and some cloudy? In the main this depends upon whether the air is light, and therefore slowly rising, or whether it is heavy and falling. It does not depend primarily upon how much moisture there is in the air for often there is just as much water vapor in the air during fair weather as during a rainstorm.

In a volume of air sufficient to fill an ordinary school room there is an average of about a quart and a half of water. The amount differs in different parts of the country and is considerably greater in summer than in winter.

It is only necessary to have the air cooled sufficiently in order to have some of this water separate out in the form of rain. The usual method by which it is cooled is to have it ascend and therefore expand. A rise of 1000 feet cools the air a little more than 5°F.

There are several conditions which cause air to rise. One is warmth. Let go a fine light wisp of cotton over a hot stove and see it go up. The great amount of rain at the Equator is largely due to the great heat causing air to rise. But in our latitude the heat of a summer day may be sufficient to start a column of air upward like smoke. It is invisible until it arrives at a level where the coolness is just sufficient to condense microscopic globules of water from it to form a cloud.

Above this layer, as the column of moist air still rises the cloud builds up into the familiar "thunder cap," level at the base and rounded at the top.

When the drops become large enough to overcome the up draft they fall as rain.

To show the cooling effect of expansion hold a thermometer bulb in the escaping air from an automobile or bicycle tire. (The air within the tube should first be allowed to come to room temperature.)

To show the formation of a cloud, if an air pump is available, put a stoppered glass flask containing a little water under the bell jar. Sudden expansion when the stopper blows out forms a cloud.

Other causes than warmth make air ascend. Water vapor is lighter than dry air in the ratio of 9 to 14.5, and therefore humid air is light.

Wind blowing up the slopes of a mountain range produce familiar whitecaps and thunder storms of the mountain tops.

The most important and widespread cause of rising air and clouds and rain in the latitude of the United States is the wave like succession of low pressures which travel from west to east across the country. These "lows" separated by "highs" follow each other like the troughs and crests of ocean swells. The "low's" eastward motion is approximately equal in speed to that of a railroad train. The low is often so large that it covers several states causing rain in all of them at the same time.

Pupils at this point should become familiar with weather maps, and the action and construction of a barometer. Isobarometric lines and isothermal lines should be clearly understood.

To make a barometer seal in a gas flame one end of a 36-inch piece of glass tubing the size of a lead pencil. Fill it with mercury with a medicine dropper, and invert it in a cup or glass of mercury.

A better plan is to pass the tube through a two holed rubber stopper before inverting it, and let the reservoir for mercury be a wide mouthed bottle such as a vaseline bottle. Then, by blowing or sucking through a tube in the second hole, increase or decrease of pressure is shown by the rise or fall of the column of mercury.

To invert the filled mercury tube in such a bottle without spilling the mercury draw a wide rubber band tightly over the open end.

Wind direction is the next logical topic of discussion in connection with the eastward moving "lows" which bring our storms. The inward and counter-clock-wise motion of air should be learned from typical storm maps. Then it can be understood why an east or south wind is likely to bring rain. Wind blows in the face of the storm which really comes—not *with* the wind—but from the west *against* the wind.

In connection with observations of wet and dry bulb thermometer readings there is much to be learned about the physiological effects of temperature. A wet bulb thermometer is easily made by putting a piece of muslin around the bulb of an ordinary thermometer, and letting it hang in a cup of water an inch or less below.

To get the wet bulb reading first use a fan vigorously upon it for a minute or more to produce as rapid evaporization as possible.

If the air were thoroughly saturated, as is seldom the case, no water would evaporate, therefore the two therometers would

read alike. The lower the percentage of relative humidity the greater the difference in the two readings.

From a physiological point of view the effective temperature is more nearly that of the wet bulb thermometer. Perspiration evaporating carries off heat but with high relative humidity there is little evaporation. The effect of wind as a cooling agent is explained by the result of fanning the wet thermometer.

A study of the "dew point," and the reason for dew on the grass may very simply be carried out by gradually stirring ice into a bright tin can of water, taking the temperature as soon as a mist forms on the can.

Mildly interesting as may be the study of thermometers, barometer and dew point and cloud forming apparatus, the more exacting pyrotechnics of the subject of weather will appear when we study the thunder storm. Especially will this be so if we can make some imitation thunder and lightning by the discharge of a Leyden jar.

As the rubbing of a glass rod during dry weather with silk will so electrify the rod that it will pick up bits of paper so in the turmoil of a rapidly changing thunder cloud the droplets which constitute the cloud become electrified. It has been proved by experiment that a fine spray blown up into the air becomes negatively charged and the larger drops remaining below positive.

A negatively charged cloud finally reaches such a tension that the resisting power of the air is broken down and a neutralizing flash leaps to some other cloud or to the earth. The sound we call thunder is the result of a strong wave of compression started in the air by the sudden expansion of the intensely heated air. The bursting of a paper bag struck by the hand illustrates such a sound wave.

Since sound travels a mile in five seconds the distance to the flash can be measured by observing the time between flash and thunder. As the flash is often a considerable fraction of a mile in length the sound does not come as a single clap, due to unequal distances to different parts of the flash. Echo also adds to the effect of "roll" of the thunder.

As practical information pupils should be taught to avoid seeking shelter during a thunder storm under an isolated tree. Hill tops and wire fences should also be avoided. Indoors is safer than out.

A thorough study of lightning rods has recently been made. Dr. F. W. Peek, of the General Electric Company has suspended

a broad sheet of metal several feet above the floor to represent a cloud and charged it with several hundred thousand volts of electricity. Flashes would leap from the "cloud" to the floor. By setting up little lightning rods on the floor he found that a rod would protect a radius around it of three times its height. That is if the rod is four feet high lightning will not strike within twelve feet of it.

But lightning rods *must* be well grounded, and they should have no sharp turns. Lightning wants to follow as straight a course as possible to the ground.

A SCHOOL GREENHOUSE.

By Ruth Allerdice,
Shortridge High School, Indianapolis, Ind.

Halfway along the south exposure of the new Shortridge high school in Indianapolis and breaking the line of its second floor windows is a glass greenhouse, 27 feet long and 10 feet wide, the value of which to the botany classes a year's fair trial has proved to our satisfaction.

The structure may be described briefly. A tile floor with two drains in it has successfully taken care of the water menace. The wall is of brick tile to a height of four feet, above which the house wall, broken by four wide windows and a pair of double doors, is of rough plaster. The rest of the structure is of glass set in an iron framework. Two easily operated windows run the length of the room—one along the line of the eaves and one at the peak of the roof. A hose connection makes watering the plants a simple matter. Six low steam radiators controlled by a thermostat are set along the south side of the greenhouse and directly above them is built the bench, 4 feet wide and as long as the room itself.

We entered the new building in December, 1928, and found that our first problem was to reduce heat and glare. A good coat of calcimine was applied at small expense to the inside of the roof and needs to be renewed twice a year. A tinner made pans to fit the tops of the radiators. These are kept filled with water. The bottom of the bench is covered with sand which, as it is sprinkled every day, adds greatly to the evaporating surface in the room. The moisture content of the air is thus kept high

enough to make conditions favorable for growing plants.

The heat is of course provided from the school heating unit and only once has a breakdown made it advisable to move the plants to the adjoining recitation room. Of course during the summer vacation everything is moved out.

The watering of the plants is taken care of by an assistant who also does much in the way of the necessary shifting and rearranging, spraying and pruning of the potted plants.

To make the room attractive has not been difficult as families and friends of our pupils are glad to send in for wintering the ferns, begonias, and other plants which they know do not thrive in the drier air of their own houses. On the other hand in June we find many who are willing to take our plants as summer boarders. A large percent of these are brought back well-grown and hearty after the vacation months outdoors.

We recognize the unusual character of our equipment and are grateful; we acknowledge the pleasure of handling living material; the real fun of the project, however, comes from the pleasure most of our pupils take in it.

Of course in the nine classes which use the greenhouse some individuals become keenly interested. Last year a group of boys sponsored what they called the great American Desert, a collection of some eight or nine xerophytic plants, and great was the triumph when the prickly pear bloomed. This year the cactus collection persists but the center of interest has shifted to the other end of the bench where John H. is raising a grove of turpentine pine seedlings which obligingly arch their way up above the sand in from two to three weeks time. A group of girls is layering English ivy and potting pieces of it as it developes roots. A boy who travelled through the west last summer asked to plant seeds of yucca palm which to his surprise came up like sturdy blades of grass.

The classes as a whole use the greenhouse for certain projects. In the fall each child in the laboratory classes buys one paper white narcissus bulb. Growers volunteering at each table take the bulbs home and start them in

the dark. On an appointed day they are brought in to the bench and from that time until they bloom interest runs high. When the majority are in flower judges are selected to score them on various points. This procedure is of present interest and may provide a basis for taking part in neighborhood flower shows at some future time in their lives. We are attempting to amplify this phase of the flower work by holding in the spring an iris show, children bringing stalks from their own gardens.

Not infrequently the glass house provides us with material for the laboratory. One day we brought in a battery jar containing Spirogyra in Knopp's solution set away on the bench some two months earlier in the hope of inducing zygote production. The thrill of discovery was shared by the whole class when one of its members mounting material from the side of the jar above the water line found not zygotes but the delicate rootlets put out from vegetative cells in the attempt to survive the long, slow process of drying out. That find illuminated for all of us the adaptation of water plants to the land habit.

From Christmas on we find it possible to use the greenhouse in illustration of class material. Propagation by roots, stems, leaves and seeds may be started and observed in all stages. The bench of sand with bottom heat and ample water gives ideal conditions for the striking of roots and this phase of the work is most successful. We find Bryophyllum, Crassula, Coleus, English and Kenilworth ivy along with begonia and geranium to be almost foolproof.

Stages of seedling growth may be admirably studied with such equipment as ours. Last spring we grew flats of marigold, columbine, hardy pinks, and zinnias and sold them for planting out in May.

We have had some valuable lessons in insect enemies and their control.

This summarizes only briefly the problems and rewards of our school greenhouse. We are enthusiastic about it because it both centers and diffuses interest, and because in the very nature of the material it can never become cut and dried.

DIFFRACTION OF SOUND BY A GRATING OF VARIABLE INTERVAL.

By Frances Savage,

El Paso, Texas.

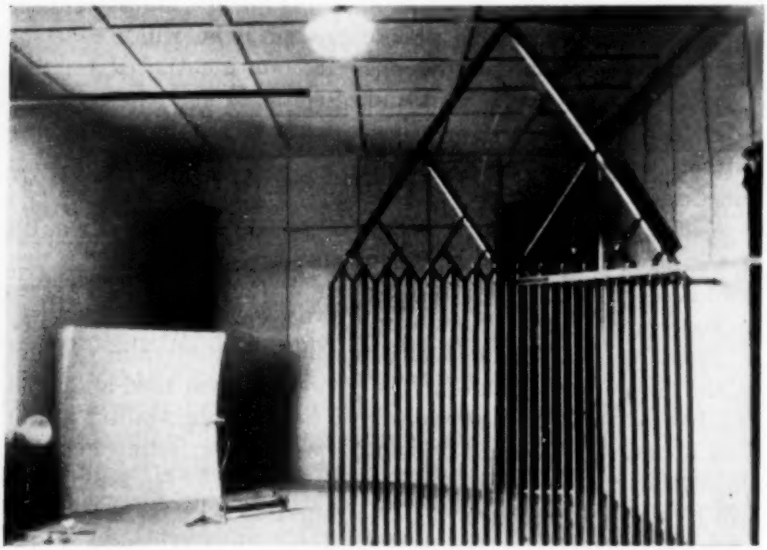
In the laboratories at the University of Texas certain diffraction experiments, heretofore done only with light or ultra-sonic frequencies of sound, were carried out and a demonstration not previously made in either light or sound, of the accoustical equivalent of the statement that the production of a continuous spectrum by a grating is no proof of the periodic nature of the disturbances sent out by the source, was made. No doubt, one interested in the various phenomena of light will find some items of interest among the pages recounting the experiment since the phenomena of light and of sound are so similar.

Little research work had been done in the field of sound diffraction during previous years, due probably to the great difficulties encountered in securing conditions suitable for experimentation, and no one heretofore had attempted the use of a grating for the diffraction of audible sound. Only a few, Lord Raleigh, W. Altberg, F. A. Schulze, E. Diechmann, Arthur L. Foley and Wilmer H. Souder, G. W. Stewart and H. Stiles, A. Tricca, and K. Palaiologos interested themselves in research on the diffraction of sound in the period between 1880 and 1923, and few of them actually obtained measurable results; but in each instance, either ultra-sonic frequencies or frequencies just above the audible range were used as a source and reflection difficulties limited the measure of success.

The experimental work at the University of Texas was conducted in a room which had been designed and used as a radio broadcasting room. The walls were of "Celotex," so cut and applied as to insure a minimum reflection of sound; the windows and doors were draped with heavy velvet hangings; and, as an extra precaution, an abundance of one and one-half inch felt was used about the source of sound, on the floor, and at vital points on the wall to insure better absorption.

The grating itself was quite multiplied in size compared to the size of the grating ordinarily used in light experiments, and it differed in one fundamental respect from the grating for light: the interval of this sound grating was variable. The grating was constructed of 33 triangular shaped wooden elements, four and one-half feet long. The elements were held in place by a system of expanding triangles and movable joints which

made the continuous variation of the interval between the elements possible. The movable joints bound the elements together on both ends and the system of triangles were attached to the upper end of the elements. Wood, iron, and "duralum" were used variously in making these triangles. A weight, attached by means of a pulley and a rope to the apex of the largest triangle, hung above the grating and compensated in a measure for its weight, helping to keep the entire system balanced and enabling one to open and close the grating with greater ease and smoothness.



The triangular shape of the elements allowed a maximum reception and reflection of sound from any certain angle by and from, respectively, their faces and the faces were painted with white enamel to insure a better reflecting surface.

The sound was directed on the grating by means of a parabolic reflector, four feet square, and was focused after reflection by another reflector identical with the first. The reflectors were built on a heavy wooden frame with a surface of Keene Cement, one and one-half inch thick. This surface was primed and then enameled in order to aid reflection. The source of sound was placed at the focus of one reflector. The sound, originating at this focus, was reflected as a train of parallel rays upon the grating and in turn was reflected from the faces of the elements and fell upon the second reflector which was

placed in a position symmetrical with the position of the first reflector. Here at the focus of the second reflector the sound was again concentrated. The ear in some instances and electrical apparatus in others were used as detectors.

The electrical apparatus consisted of a carbon microphone placed at the focus, in conjunction with a resistance coupled amplifier and a vacuum-tube voltmeter. Any variation in the intensity of the sound at the microphone varied the current through the microphone which, after being amplified, was read directly from the voltmeter.

Using the ear as a detector, such irregular disturbances as the ticking of a watch, the buzz of a high frequency buzzer, the noise produced by the clapper of an electric bell from which the bell itself had been removed, and the rattle of a bunch of keys, were studied. The effect produced by opening and closing the grating, using the rattle of the keys as a source, was characteristic of that produced in each case mentioned. While the source was entirely lacking in periodicity, yet the sound heard at the focus of the reflector as the grating closed, was a musical scale. The significance of this can not be overlooked. Newton stated that the existence of a continuous spectrum produced from a white light source proved the presence of all vibrations in the source. Here the noise of the keys corresponds to a white light source and the spectrum was continuous, yet one can no longer claim that the grating does not manufacture the wave-length and that it merely selects the frequency from among the ones present. From this noise of the keys, the grating produced an artificial frequency depending upon the width of the opening between the elements. When these elements were close together, the artifical frequency was high and became lower as the elements separated. This grating broke up the single pulse of sound into a series of pulses which arrived at the focus of the second reflector at definite intervals, due to the fact that each pulse from each interval of the grating travels over a different route and the difference in the distance traveled by successive pulses was the same. Thus, to an irregular disturbance was imparted a periodic character, pulses from the successive intervals reaching the detector at definite successive periodic intervals of time, the period depending not on the source of sound but on the interval of the grating.

Next, a periodic sound of a definite frequency was examined. A telephone receiver, vibrating with a vacuum-tube oscilator

at a frequency of seven thousand per second was used as a source. The 33 element grating produced a line spectrum perfectly discernible, using the ear as a detector, the intensity remaining practically constant until the interval producing a maximum was approached, then a maximum of unmistakable intensity was reached and passed as indicated by a pronounced resonance followed by a rapid decrease in intensity. By using the arrangement including the voltmeter, as detector, it was possible to obtain data for plotting an intensity curve showing intensity at various successive intervals of the grating as the grating slowly closed. Since the frequencies passed by a carbon microphone are limited to those well below five thousand, the frequency of the source was necessarily changed before readings for this curve could be taken. The first frequency used was four thousand. From the data taken at this frequency it was possible to locate the position of the first maximum with sufficient accuracy to permit the wave-length to be computed to an accuracy of less than one percent error, using the formula

$$\lambda = 2A\cos\theta$$

where "A" is the distance from one element to the next and "θ" the angle of incidence. The experiment was conducted with θ equaling 45°.

Another advantage in the use of the electrical hook-up for detection was that by placing the vacuum-tube voltmeter near one end of the grating, a single observer could operate the entire arrangement from one position. This was desirable since the detecting apparatus was very sensitive to disturbances, making the voltmeter very difficult to read under the best conditions.

By replacing the 33 smaller elements of the grating with 17 larger elements, similar in design but of twice the cross-sectional area, the maximum interval between two succeeding elements was increased to about six inches, making it possible to obtain data for a curve with two maxima by using the same frequency of four thousand as a source.

Since the intensity of the source at this frequency was small compared to the intensities of many outside disturbances, and since a frequency of two thousand gave a louder source and the microphone responded to this frequency more readily, the readings of the voltmeter at this last frequency were more characteristic of points on the curve, so supplied data for a more accurate curve representing a single maximum. In reality, the ordinates

on the curve did not represent intensities but were only roughly proportional to the intensities, due to the distortion produced by the electrical system and to the variable width of the slit.

While the peaks of the plotted curves were sharp, in each instant the curve was characterized by a decided breadth at the base of the maxima. This was probably due to the large size of the microphone which acted as the receiver and to a variation in the number of elements intercepting the train of sound pulses. The entire grating did not lie within this train originally, and the number of elements intercepting it decreased as the interval increased. Using the formula for the grating for light:

$$I = A^2 \frac{\sin^2 \frac{Ne}{2}}{\sin^2 \frac{e}{2}}$$

where "I" is the intensity, "A" the amplitude, "N" the number of elements, and "e" the phase difference, and applying it to this sound grating, "N" becomes a variable, tending to reduce the number of minima between any two maxima below the number which would exist were "N" a constant. Primarily, the intensity depends upon the width and the shape of the opening between the intervals; otherwise it depends on the terms

$$\frac{\sin^2 \frac{Ne}{2}}{\sin^2 \frac{e}{2}}$$

taken from this above formula.

SHOULD BIOLOGY BE REQUIRED IN HIGH SCHOOL?

By Lynda Webber,

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I am of the opinion that it would be a good thing to require biology as one of the basic sciences in our high schools, provided the social aspects of it are emphasized. There aren't many courses that lend themselves to the development of the socially worthwhile aims as biology does. Also, since health statistics obtained during and after the war are convincing that personal hygiene needs to be stressed in our rising generation, it seems both feasible and economical to include human biology in the general biology course.

With these phases of work incorporated, I believe it would be most worthwhile to require this life science. However, before such a step can be taken, our instructional force must be thoroughly prepared for the work. No good can come from required courses taught by untrained teachers.

HOW WE SOLVE PROBLEMS[1].

By Paul Ligda,

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Introduction.

The teaching of elementary algebra may be divided into three parts:

1. The teaching of the mechanics of algebra, that is of the symbolic notation and of manipulative devices. The main aim is to develop the ability to solve readymade equations of various types.

2. The teaching of the application of this machinery to the solution of verbally stated problems. In other words: the teaching of the art of obtaining equations from verbal statements that compare quantities or describe relationships.

3. The teaching of the use of mathematics in life work, developing habits of quantitative thinking, habits of perceiving relationships among quantities, and of formulating and solving problems.

While the first is fairly well organized and produces fairly reliable results from the standardized testing and the college entrance examination viewpoints, the second is still in a very unsatisfactory state, and the third is hardly recognized by academic teachers. The result of this condition of affairs is that, as shown conclusively by a number of published researches, pupils cannot solve comparatively simple problems. The business world informs us that school graduates do not seem to have much "number sense." The ability to think in terms of quantities and relationships seems to be possessed by very few.

The main purpose of this paper is the analysis of a well known traditional procedure, sometimes misnamed *Problem Analysis*, and usually summarized into a set of "*Directions or Suggestions on how to solve Problems.*" It will be shown presently that this procedure is, to a large extent, responsible for the present condition of affairs, inasmuch as it hinders real analysis in elementary instruction, the kind of analysis that would function in the life work of pupils.

Inadequacy of traditional directions. We usually begin the teaching of algebra with the presentation of simple equations

[1]This lecture is the eighth of a series of fourteen on the use of the fundamental concepts of mathematics in the systematic analysis and solution of quantitative problems, as delivered to an Extension class in the Fall term of 1927. A considerable amount of material is taken from the writer's *The Teaching of Elementary Algebra*, by permission of the publishers, Houghton Mifflin Company.

of the type $ax+b=c$. After the class has learned to solve this class of equation we assign some simple verbal problems, giving directions of the following type:

State what is given and what is to be found.

Represent one of the unknowns by means of some letter; represent all of the other unknowns in terms of the same letter.

After a study of the relations between the parts of the problem, express the verbal statement in an algebraic equation.

Solve and check.

These directions are directions in name only, for the simple reason that the authors do not explain what they mean by *relations* and *parts*, nor how one is to know when "all the other unknowns" have been found. They do not illustrate what they mean in the model solutions incorporated in texts. The writer has yet to see a textbook that states definitely: "This is a part; these are the other parts; and these are the relations among these parts." Finally no textbook states that "what is given" is frequently *implied* in a very indirect way. The result of this reticence is that most pupils fail to solve any but the simplest problems, such as they could solve before they began the study of algebra.

Let us analyze a few problem solutions and see whether it is possible to give more meaningful directions.

Problem 1. John is 20 years older than Sam. In 15 years he will be twice as old as Sam. Find the present age of each.

Traditional procedure:

Let $x=$ Sam's age in years now,
then $x+20=$ John's age now,
and $x+15=$ Sam's age in 15 years,
and $x+15+20=$ John's age in 15 years.

We may now write an equation which tells us the same thing as the original verbal statement. (Or; by the conditions of the problem. Or: Relation of equality. Or, any phrase showing that the solver does not perceive clearly the statement of comparison: John's age in 15 years is twice Sam's age in 15 years.)

$x+35=2(x+15)$, etc.

This procedure is well known, and we do not perceive any defects until we solve in a different way:

Let $x=$ Sam's age in 15 years,
then $2x=$ John's age in 15 years,
and $x-15=$ Sam's present age,
and $2x-15=$ John's present age.

We may now write an equation which tells us the same thing as, etc.

$x-15+20=2x-15$, etc.

It can be seen that there is something wrong with the sentence "We may now write . . ." for we can write two different equations, each of which "tells us the same thing as the original verbal statement."

"Relation of equality" is also ambiguous for we seem to have two relations of equality. "By the conditions of the problem" is equally misleading, for apparently we use different conditions for the different equations. The second statement of comparison used for the second equation is clearly: John's age (now) is 20 years more than Sam's age (now).

The traditional phrases then are out ofplace in the teaching of "the exact science."

The groping way. Attention is first attracted to the statement that John is 20 years older than Sam. This is a statement of comparison between two like quantities, and was formerly called an arithmetic ratio. Unfortunately the word *ratio* has lately lost its former meaning of "the expression of the fact that two quantities are compared" and become a *quotient*, a useless duplication of names. If we have been taught that statements of comparison may be changed to statements of equality by completing the process of comparison and forming a judgment of equality we proceed as follows:

We write the two quantities, using any convenient phrases, words or symbol, thus:

	John's age	Sam's age
or	J	S
or, (less desirable)	X	Y

We contemplate the two quantities in juxtaposition (compare them) and reason:

This (John's age, or J, or X) is greater than that (Sam's age, or S, or Y). In order to make the two equal what must we do? Add 20 to the smaller. The statement of equality is then

John's age = Sam's age + 20.

This is *one* of the things that the "original verbal statement tells us" (rather indirectly); *one* of the conditions of the problem; *one* of the relations of equality. The other one is,

In 15 years John will be twice as old as Sam.

A sentence which, when submitted to a process of conscious comparison with resulting judgment of equality, may be restated

in the equational form:

John's age (then) = twice Sam's age (then).

The scheme of relationships may be displayed in a relation diagram, equations being read vertically as well as horizontally:

$$\begin{array}{ccc} \text{John} & & \text{Sam} \\ 15 & & 15 \\ + & & + \\ a & = & X+20 \\ \| & & \| \\ c & = & 2d \end{array}$$

We have now a definite plan of solution. We can select any one of the four unknowns for our x and express the remaining three in terms of x, 20, and 15, that is, solve three of the above four equations for the other unknowns. Thus letting X = Sam's age,

John's age $= a = X+20$

Sam's age in 15 years $= d = X+15$

John's age in 15 years $= c = 2d = 2X+30$

We now substitute these values in the remaining equation

$$c = a+15$$

$$2X+30 = X+20+15.$$

The diagram shows that the problem can be solved in four different ways according to the unknown selected, that is we can write four different equations which tell us "the same thing as the original statement," four "statements of equality," and four different "conditions of the problem."

The analysis illustrated above requires considerable work on paper because it shows the complete chain of thoughts, the analysis and the synthesis. The traditional method of solution requires very little paper work because it shows only the results of some dimly perceived mental analysis. But a certain amount of work must be done, mentally or on paper. Work on paper is under the control of the teacher. He can explain and assist at any point. Mental processes are beyond the teacher's control. He can only pray that the children learn "inductively." About the only excuse in defense of the traditional method is that it leads to a "simple" equation, that it simplifies the symbolic work. But mental work is automatically increased. The question now arises: Were symbols invented and perfected in order to facilitate quantitative thinking? If so why not use them whenever they may assist analysis?

Problem 2. A train leaves a station and travels at the rate of 40 miles an hour. Two hours later another train leaves the same

station and travels in the same direction at the rate of 55 miles an hour. When will the second train pass the first?

When teachers and authors show the solution by the traditional method they proceed as follows:

Let x = the number of hours that the fast train travels,

1. Then $x+2$ = the number of hours that the slow train travels,
2. and $55x$ = the distance that the fast train travels,
3. while $40(x+2)$ = the distance that the slow train travels.
4. By the conditions of the problem

$$55x=40(x+2), \text{ etc.}$$

But suppose that, instead of being teachers or authors, we are merely parents who are trying to help our children to understand how problems are solved. We would promptly find that we must introduce some supplementary explanations. After the word *then* of the first step we would add: Since the slow train travels two hours longer than the fast train . . . .

After *and* of step 2 we would add: Since distance = rate × time, 55 is the rate and x is the time . . . . .

After *while* of step 3 we would add: Since distance = rate × time, and 40 is the rate while $x+2$ is the time . . .

After *By the conditions of the problem* we would add: That is, since the distances are equal, therefore . . .

In short we would handle the problem somewhat like a geometric theorem.

The children understand the problem perfectly. But just as we are congratulating ourselves, we receive a jolt: "Where did you obtain all this information? How did you happen to think of all the 'sinces,' especially the last? When we read the problem these statements do not suggest themselves. What are the words that suggest them to you? We cannot learn to solve problems by imitating you. We do not want your thoughts, your results, your tricks in solving special problems. We want your general method of attacking problems."

The following will describe the writer's attempt to help the children out of their bewilderment.

The solution of a problem may be considered to consist of four somewhat overlapping parts: the analysis, the synthesis, the translation into symbols, and the symbolic solution. The analysis consists in breaking the verbal statement into distinct and separate parts and finding the relationships among these parts. The synthesis consists in rearranging the results of analysis in such a way that equations are obtained. The last two parts do

not need discussion.

The first step in a systematic analysis consists in finding the number of "situations." The second step consists in finding the "characteristic formula" involved in each situation.[2]

In our problem we find two "situations": the fast train and the slow train. The characteristic formula involved is the well known formula $D=RT$. These two steps complete the preliminary analysis.

What follows is, to a certain extent, mechanical. We write the formulas vertically in the diagram on the left.

$$\begin{array}{cccccc}
\text{Fast train} & \text{Slow train} & \quad & \text{Fast train} & & \text{Slow train} \\
D & d & & D & = & d \\
\| & \| & & \| & & \| \\
R & r & & 55=R & & r=40 \\
\times & \times & & \times & & \times \\
T & t & & 2+T & = & t
\end{array}$$

Final analysis, beginning of synthesis, and of translation into symbols. We now ask ourselves the following questions, *suggested by the diagram.* What does the problem state or imply about the distances D and d; the rates R and r; the number of hours T and t.

The answers are

1. The distances are equal or $D=d$. This is written in the diagram.

2. The rates are 55 and 40 respectively. This is also written in the diagram.

3. The slow train travels 2 hours longer than the fast train. This statement of comparison is changed into a statement of equality by asking ourselves the question: What would make one number of hours equal to the other number of hours? The answer is: add 2 hours to the smaller. That is, $T+2=t$. This is also written in the diagram. (The diagram to the right shows the condition of affairs at the completion of the analysis, synthesis, and translation.)

The diagram is now complete. We know that the analysis is ended because every quantity is either completely described (Thus $R=55$, and $r=40$), or related *equationally* to the *like*

[2]The meaning of these terms will be made clear presently. For a more exhaustive discussion the reader is referred to *The Teaching of Elementary Algebra*, page 113. The characteristic formula may be defined here as the fundamental formula of indirect measurement: The total number of units in the quantity measured = the number of units in the standard of measurement × the number of times the standard is applied. In elementary algebra problems the standard or rate is constant, hence these problems are sometimes called constant rate problems. This formula may also be said to express the functional relationship between two quantities.

quantity in the other situation (Thus $D=d$, and $T+2=t$).

We have four unknowns and therefore may solve in four different ways. Selecting T for our unknown and substituting X for T in the diagram

$$\begin{array}{rcl} \text{Fast train} & & \text{Slow train} \\ D & = & d \\ \| & & \| \\ 55=R & & r=40 \\ \times & & \times \\ X+2 & = & t \end{array}$$

Using the diagram for our guide we proceed to express the other unknowns, D, d, and t, in terms of X.

Since $D=RT$ and $R=55$, $D=55X$.

We find in the diagram that $t=X+2$.

Since $d=rt$, $r=40$, and $t=X+2$, $d=40(X+2)$.

We have used every equation but $D=d$. Substituting the above found values of D and d in the last equation

$$55X=40(X+2), \text{ etc.}$$

An expert solver would use only one diagram, crossing out D, d, and t, and "expressing their values in terms of X." The work is so obvious that the diagram is omitted.

If we had selected D or d for our unknown, we would have obtained $T=X/55$, $t=X/40$, and finally $X/55+2=X/40$. Some writers would then have classified the problem as one "leading to a fractional equation."

Problem 3. A purse contains 15 coins, both nickels and dimes, and the value of the collection is 90 cents. How many coins of each kind are there?

A variation of the traditional method is sometimes found in some modern textbooks. It is an improvement to a certain extent, but its defects will appear in the following analysis.

Solution. By one of the conditions of the problem

Value of dimes + value of nickels = 90 cents (1)

Let $X=$ the number of dimes (2)

then $15-X=$ the number of nickels (3)

and $10X=$ the value of the dimes in cents (4)

and $5(15-X)=$ the value of the nickels in cents (5)

Substituting 4 and 5 in 1,

$$10X+5(15-X)=90$$

Discussion. Step 1 is placed at the beginning of the solution for pure convenience, inasmuch as it indicates the more or less clearly perceived general plan of the solution that follows.

We are going to express the two unknowns in the left member of 1 in terms of one of the two unknowns left: the number of nickels or the number of dimes. It should be noted that the phrases *value of dimes* and *value of nickels* are in reality symbols for unknowns. We could just as well have used single letters such as V and *v*.

Step 2 does not need any comment, excepting that the semi-equational form is objectionable. It would be preferable to write: Let X *stand for* the number of dimes.

Step 3 deserves serious consideration. The solver found the statement "15 coins, both nickels and dimes." He rearranged it *mentally* in form suitable for translation into algebraic language: Number of nickels + number of dimes = 15. He then solved it *mentally* for "number of nickels." The latter is an unknown quantity. In order to delude himself into the belief that he was solving by means of a "simple" equation he did not indicate, by means of a single letter, that this quantity was unknown. The word "then" indicates all this reasoning.

Step 4 indicates the recognition of the characteristic formula: Total value of dimes = value of one dime in cents × number of dimes, a functional relationship. This step then can be taken only after this functional relationship is recognized. The use of "the value of the dimes in cents" instead of a single letter does not alter the fact that we have here an equation: $V=10D$. The use of the phrase is then objectionable because it does not show that we have here an equation, the translation of a statement of relationship, even though the statement is implied. One of the recommendations of the National Committee was to the effect that teachers must point out relationships whenever they occur in problems. If writers of textbooks pointed out a few relationships once in awhile teachers might also acquire the recommended habit.

The remarks on step 4 apply with equal force to step 5. It should be noted in addition that not only are we "expressing one quantity in terms of another," but we are also expressing one quantity, the number of nickels, in terms of three quantities, two known and one unknown. Mathematicians teaching or writing textbooks often forget that numerals are not merely "constants" or "pure numbers," but that they also stand for quantities just as much as the letters used in symbolizing unknowns. From this viewpoint, in order to be complete, the above steps should include the value of the dimes and of the nickels in cents.

The recognition of the fact that the last two values are *rates* enables us to solve the problem without reducing nickels and dimes to cents. Let D = the number of dimes, N = the number of nickels. We have then

The value of dimes, expressed in nickels + value of nickels = 18

$$2D+N=18$$

Since the number of nickels is $15-D$, by substitution

$$2D+15-D=18, \text{ whence } D=3.$$

Solution by the diagram method.

We have two situations: the pile of nickels and the pile of dimes. Each situation is governed by the characteristic formula $T=RN$, total value of pile = value of one coin (the rate) × number of coins. Placing the formulas vertically in order to facilitate the comparison of like quantities.

$$
\begin{array}{cc@{\qquad\qquad}ccc}
\text{Nickels} & \text{Dimes} & \text{Nickels} & & \text{Dimes} \\
T & t & T & + & t=90 \\
\| & \| & \| & & \| \\
R & r & 5=R & & r=10 \\
\times & \times & \times & & \times \\
N & n & N & + & n=15
\end{array}
$$

Looking at the left diagram we ask ourselves the questions:

What does the problem state or imply about the total values T *and t*?

What does the problem state or imply about the value of a dime; of a nickel?

What does the problem state or imply about the number of nickels *and* the number of dimes?

The answers are: The value of the collection is 90c, that is, the sum of the values of the nickels and dimes is (equal to) 90 cents. This statement is translated into an equation and written in the diagram on the right.

The value of a dime is 10c. The value of a nickel is 5c. These equations are also written in the diagram.

The number of nickels and dimes is 15. That is, the sum of the nickels and the dimes is 15. This is translated and written in.

The diagram is now complete. Every one of the four unknown quantities is related equationally to the like quantity in the other situation and functionally in its own situation. Also every known quantity is completely described. This means that the analysis and synthesis are completed and that we may begin the symbolic solution.

We may select any one of the four quantities for our X. In

general it is advisable to select one of the two factors of the right member of the formula, because the selection of the quantity for which the formula is solved would lead to a fractional final equation. Let $N = X$.

Then, since $N + n = 15$ $\qquad n = 15 - X$
and, since $T = RN$, and $R = 5$ $\qquad T = 5X$
and, since $t = rn$, and $r = 10$, and $n = 15 - X$ $\quad t = 10(15 - X)$.

Finally, since $T + t = 90$, by substitution,

$$5X + 10(15 - X) = 90, \text{ etc.}$$

Conclusion.

It is believed that the above problems are sufficient to illustrate the method of solution. The reader may find a large number of problems analyzed and solved by the diagram method in *The Teaching of Elementary Algebra,* showing that all elementary algebra problems may be systematically attacked, analyzed, and solved. The advantages that this method presents over the traditional method are:

1. It provides an easy and uniform attack.
2. It provides a uniform analysis directed by the diagram.
3. It indicates automatically the end of the analysis.
4. It directs the symbolic solution and provides the final equation.
5. It trains in the perception and conscious use of relationships, that is, teaches the function concept.
6. Every part of the analysis and solution is under the direct control of the teacher, that is, skill in solution increases directly with practice.
7. It is actually easier to teach than the traditional method, because there is only one procedure to learn, instead of a number of "type" solutions.

About the only good that can be said about the traditional method is that teachers are used to it and find it easier to "teach" than a method with which they are not familiar. People in the United States are opposed to the Metric System on somewhat similar grounds.

A new national educational periodical, the *Junior College Journal,* will begin publication in October, 1930. It will be published by Stanford University Press, and will be under the joint editorial control of the American Association of Junior Colleges and the School of Education of Stanford University. The new journal will appear monthly with the exception of the summer months.

LET'S GET TOGETHER!*

By HOWARD C. KELLY,
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Contrary to a rather general opinion, there are a number of otherwise sane people in the East who do not believe that the universe revolves around the city of Boston—or even the Commonwealth of Massachusetts. As one of those heretics, it is a particular pleasure to talk today to the members of your association, and to present what some of us believe to be a real educational opportunity. In fact, the results of a little private investigation which has been going on for the past three years have convinced us thoroughly that there is in general science an almost untouched problem which calls for the collective thought and action of general science teachers. It has appealed to us so strongly that we would gladly initiate the work and attempt to carry it through—if we had the organization.

Every section of the country has its own peculiar characteristics and advantages. An old college professor of my acquaintance used to be very fond of saying, "There have never been any two people in the world who were just alike. If there were, there wouldn't be any use for one of them." As with individuals, so with groups. You have what we lack, an association numerically strong, educationally alert, and sanely progressive. Such an association can sponsor an educational project, and provide the weight necessary to give it national recognition. You have done such things before. I hope you may do so again.

As I come to you today, I could wish that my ancestors had been thoughtful enough to have been born in Scotland, because the Scotch furnish us with the most convincing and persuasive speakers in the world. Do you know why? It's a gift! Would that I had it in such measure that you and I and others might be led to get together, to drop for a while our discussions about topics for study, special methods, and the like, and come to some workable agreement on the foundation stones—the basic general aims and the educational principles which should precede subject matter, methods, and testing.

A professor in one of our universities recently made the

*Read before the General Science Section of the Central Association of Science and Mathematics Teachers at Chicago, November 29, 1929.

statement that modern education is based on fear—not that old "fear of God" which the teacher used to instil in a pupil by rod or strap, but a fear much more widespread. He declared that the teacher fears the principal; the principal fears the superintendent; the superintendent fears the board of education; the board of education fears the parents; the parents fear the children, and the children fear—nothing at all.

Whatever quarrel we may have with so broad a generalization, we are forced to admit that general science in our modern school systems owes its existence to fear. The science teachers were afraid; the administrators were afraid, and general science got its start.

It matters little to whom we grant the honor of initiating the first course in general science. Let's agree with Twiss that the date was 1869, and that the lectures given by Professor Thomas H. Huxley on the Thames basin and the relation of its history to the life of people in London formed the subject matter. Surely anyone would be a better science teacher for a study of those lectures. Nevertheless, they exerted very little influence on American school systems. Indeed, as some of us can remember, in the decade previous to 1900 high school science was very much specialized. "Mathematical treatment" was frequently carried to extremes. Laboratory work was at times divorced not only from the subject matter discussed in the class room but even from ordinary "horse sense." Josh Billings' famous remark, "There's one thing 'bout common sense, 't aint common" might with a fair degree of justice have been applied to the instruction in many laboratories. The subject was taught, in preference to the pupil.

Naturally the pupil rebelled. He rebelled in the only way open to him. He refused to choose the science courses offered to him as electives, and the number of science students dwindled to such a degree that the teacher feared for the existence of his subject.

Let me take a particular school as a typical example. A new high school building had just been completed. At that time, and in that section, biology was the only subject thought worthy to even be considered as an introduction to science. The course offered to the freshmen, and re-

quired of them was one in "general biology." It was made up of a half-year of zoology and a half-year of botany.

The zoology consisted of the dissection and careful drawing of the component parts of a cricket, a grasshopper, an earthworm, and a crayfish. The notebooks were either hopelessly bad or works of art, but few, if any, gave evidence that the word "function" was in the pupil's biological vocabulary.

The botany, likewise, was mainly a succession of drawings. Leaves, stems, buds, and flowers were represented, and their parts duly labeled. Some analysis of flowers was made, and during the last two weeks there was a short study of the growth of a seedling.

To some the work was attractive. To more it was either boresome or disgusting. "How we hated that old bugology! I can smell the pickle yet!" said one pupil fifteen years later. To state the matter very conservatively, the work did not arouse an enthusiastic interest in science.

This unfortunate introduction reacted upon the whole science department. The pupils failed to elect physics and chemistry, and the number taking science work decreased alarmingly. The teachers were afraid. The principal and superintendent shared the fear.

There were many discussions, and during one of these, the principal, who had formerly been the head of the science department, and the superintendent, who has since added to his reputation in one of our large universities, had a vision. With little regret they threw aside the old course entirely, and set about building a new and different one which should (a) give the pupil a broad, general view of the whole field of science; (b) be presented in a fashion which should interest the pupil, and (c) be organized with such definite relation to the pupil's life that he should be able to see for himself that the science of the school and the science of the outside world were one and the same. Out of this experiment evolved a widely known and quoted general science course.

In other places other schools and teachers were having similar experiences, and a considerable number, quite independently, visioned the possibilities of an introduction to science which should be general instead of specialized.

Each, however, developed his idea along the lines of his own personal convictions, experiences, and prejudices. Each had imitators, and thus there has grown up a number of groups, each group representing a certain trend in the teaching of general science. Each group calls its work "general science," though the differences between them are many and great.

For example: (1) A teacher said, in answering a questionnaire, "I follow the advice of Prof. ————, and I never know when I go into the classroom what we are going to do that day." This reminds some of us of what I believe was the first general conference on "first year science" which was ever held. Dr. Woodhull of Columbia presided, and Dr. Mann of Chicago was one of the principal speakers. In the course of the discussion an agent of the state board of education of Massachusetts was asked for his opinion. He was a slightly crude, though keen, gentleman, and his reply was vastly to the point: "When I go into a hotel," he said, "I never order hash." There is still some "hash" to be found among our general science courses.

(2) Another group says, "We teach certain science concepts, certain principles, and then show the application of these." That this is ideal in aim and method is disputed by others, who say, "The scientific method arrives at a generalization *last*, not first."

(3) Quite a considerable number of courses consist of sections of specialized sciences. Physics is taught for a few weeks, chemistry for a few more, and so on. Among laymen this comes as near as any to being the prevailing view of what general science must be. Among teachers the acceptance is far from universal. Many can not see the logic of calling a section of specialized science by another name simply because the setting is changed a trifle. "As well call a nickel a dime when it is changed from one pocket to another," they say—rather illogically, we must admit. "If general science has not aims, material, and methods distinctively its own, why use the term at all?"

(4) In some sections, by state law or otherwise, there is an attempt to "standardize" the general science course. This procedure has certain obvious advantages, especially

from the standpoint of the textbook makers, and some teachers. A disadvantage was pithily stated by Dr. Otis W. Caldwell at a convention of the Connecticut State Teachers Association. "Anything which goes into a mould is likely to come out a little bit moldy."

(5) Probably the largest group attempts to arrange the selected material in the form of "general units," and frequently makes this the distinguishing feature of the work. But what are "units"? Shall they be abstract or concrete in title and nature? Shall they suggest problems, or be merely syllabi? How much material does it require to make a unit? Just what are the characteristics of a good unit? On many of these things we differ. In other words, our understanding of the term "unit" varies.

Such radical differences are possible only because we have not thought it worth while to consult and cooperate with as many as possible outside of our immediate circle. How often has a representative group of teachers from the central and eastern states met around a table to discuss the problems of general science? How often has a group represented all sections of the country?

The results of such non-cooperative development are inevitable.

(a) There is still considerable diversity in aims, though recently there has been some improvement along this line.

(b) We have no *generally accepted* principles to guide in the selection of material, in organization, and in presentation. We have no uniform standards which we may apply to aid in separating the usable from the unfit.

(c) Our terminology is not uniform. We do not understand each other's use of words.

(d) Our progress is slower than it needs to be, and we lay ourselves open to justifiable criticisms.

I would not have you think that I am disparaging the progress which has been made, or that I am pessimistic in regard to the future. Far from it. The condition of science teaching is so much in advance of what it was in 1900 that there is no comparison, *but* isn't it about time for us to get together and begin to settle our *differences?* Shouldn't we agree upon underlying *principles* before we argue and fret about details of procedure?

I bring this problem of getting together to you because your association is well situated to set up the machinery for its solution. Your geographical situation is favorable. Your reputation is well established. Your leaders are here. Cooperation will come, either through your instrumentality or that of another group, and when it does, I believe we shall have less futile discussion and more desirable progress than has been seen since general science took its place in our schools some twenty-five years ago.

ADAPTING THE SLIDE RULE TO HIGH SCHOOL CHEMISTRY.

By Hoyt C. Graham and John A. Huff,

New Mexico State Teachers College, Silver City, New Mexico.

One of the authors of this article has always found his chemistry students eager to learn to use the slide rule when they were given a demonstration of it.

In several cases entire classes purchased slide rules. The students were shown how to multiply and divide on the slide rules and encouraged to use them in solving their chemistry problems. However, no systematic instruction on manipulating the rule was given. Individual help was given when requested.

A few of these students became very proficient in using the slide rule. However, in spite of the initial enthusiasm a portion of each class lost interest before they could successfully operate the rule.

The excellent results obtained by some of these students convinced their instructor that each member of a beginning chemistry class would profit by owning a slide rule. However, since some students were unsuccessful in merely "picking up" the slide rule the instructor was convinced also that well planned class instruction was necessary.

The authors introduced the slide rule to the 1928 and present year beginning college chemistry classes. Instruction, but not systematically planned, was given during the regular class periods.

The difficulties experienced by these two college classes were carefully studied and analyzed for the purpose of outlining a method of slide rule presentation. Only two serious difficulties were found. First, the reading of scales on the rule and second, the placing of decimal points.

Reading the C and D scales is especially confusing to beginners because the subdivisions between 1 and 2; 2 and 4; and 4 and 10 do not have equal values.

We find that most amateurs have trouble in using the ordinary method, commonly employed by slide-rule-users, of locating decimal points by inspection.

Below is a brief outline of the procedure followed by the authors in teaching slide rule to the high school chemistry class in the New Mexico State Teachers College Training School.*

1. Half of each laboratory period was devoted to slide rule instruction. This amounted to forty-five minutes twice each week.
2. The first period was used in explaining the parts of the rule, such as the scales, slide and indicator. The pupils were shown how to read the C. and D scales and how to locate two digit numbers.
3. During the second period much emphasis was placed on values of subdivisions. The class was drilled on locating and reading three digit numbers.
4. The third period was devoted to locating and reading numbers involving four figures. Special attention was given to numbers containing zeros such as 105; 305; 203; 1005; 1002; and 1001.
5. The operations of the slide and indicator in multiplication and division were explained during the fourth period. The students performed the operations but the products and quotients were read without regard to decimal points.
6. Period five was devoted to the location of decimal points.
7. During the sixth period the class was drilled on solving representative chemistry problems by means of the slide rule.

After the sixth period no further class instruction on the slide rule was given.

Our method of teaching the slide rule has proven successful with this high school class. At the end of the sixth period of instruction practically the whole class was able to solve problems, by means of the rule, with accuracy and fair speed. More rapid manipulation and skill in handling the rule will come with continued use.

We believe that any high school chemistry instructor, who is fairly familiar with the slide rule, can successfully introduce it to his class if he follows an outline of instruction similar to the one which we have given. All attempts at multiplication and division should be discouraged until the reading of the C and D scales has been mastered. Little can be accomplished in either multiplication or division until the students can locate and read numbers rapidly on these scales.

Some definite method for locating the decimal point is important. Our students have been able to locate decimal points

* The authors are indebted to Instructor Charles L. Koelsche for permitting us to use the high school chemistry class for making this study.

easily by representing all numbers in a problem as small multiples of some power of ten, and then making a rapid mental calculation of the approximate result. By this method the number of digits on the left of the decimal point can be determined by simply multiplying or dividing very small numbers (usually whole numbers) and then multiplying by the proper power of ten.

A few examples will show the method of representing numbers:

$1000 = 1x10^3$	$273 = 2.73x10^2$
$100 = 1x10^2$	$760 = 7.60x10^2$
$10 = 1x10^1$	$22.4 = 2.24x10^1$
$1 = 1x10^0$	
$0.1 = 1x10^{-1}$	
$0.01 = 1x10^{-2}$	
$0.001 = 1x10^{-3}$	

An approximate result of a calculation can be made quickly as follows: $756x22.4 = \text{Approximately } (8x10^2)\ (2x10^1) = 16x10^3$ or 16000.

16000 is not the correct product of 756x22.4, but, it shows that there are five figures on the left of the decimal point.

After performing an operation, such as $\frac{19.3}{872}$, on the slide rule the decimal may be located rapidly as follows: $\frac{19.3}{872} = \text{Approximately } \frac{20x10^0}{9x10^2} = \frac{20x10^{-2}}{9} = \text{App. } 0.02$. This shows clearly that one zero belongs between the decimal and the first significant figure.

The following examples are more complicated:

$$\frac{48300x6.3x792}{23x2734} = \text{Approximately } \frac{(5x10^4)\ (6x10^0)\ (8x10^2)}{(2x10^1)\ (3x10^3)} = \left(\frac{5x6x8}{2x3}\right) x10^2 = 40x10^2 \text{ or } 4000.$$

$$\frac{516x44x0.0843}{19x7314x0.000231} = \text{Approximately } \frac{(5x10^2)\ (4x10^1)\ (8x10^{-2})}{(2x10^1)\ (7x10^3)\ (2x10^{-4})} = \left(\frac{5x4x8}{2x7x2}\right) x10^1 = \frac{160}{28} x10^1 = \text{App. } 60.$$

This method of locating decimal points can be applied to any type of problem which the high school chemistry student will need to solve on the slide rule.

The authors believe that the slide rule is a real asset in the teaching of chemistry. The advantages are twofold. First, the

time required to work a set of problems on the slide rule is only a small fraction of the time required to work them by ordinary calculations. The time saved can be spent in solving more problems or studying theory. Second, when using the slide rule the student learns to state his problem in such a way as to carry out its solution by one continuous series of operations of the slide and indicator. The slide rule operator, therefore, forms the habit of mentally analyzing problems before starting their solution. This avoids merely working for an answer.

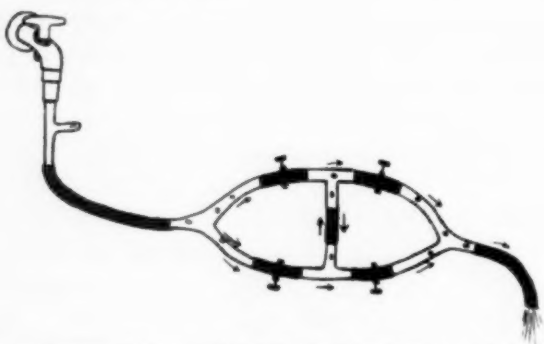
These two advantages should justify spending a few class or laboratory periods to teach a beginning chemistry class to use the slide rule.

Some chemistry teachers may object to the slide rule on grounds of inaccuracy. The reader is, therefore, referred to the topic of significant figures by Black and Conant (Practical Chemistry, Black and Conant, p. 118, The Macmillan Co., 1927).

WHEATSTONE BRIDGE MODEL.

By H. F. Cope, *High School, Medford, Ore.*

The average high school student finds considerable difficulty in performing the Wheatstone bridge experiment because of failure to understand the flow of current in the divided circuit and the part played by the galvanometer. In order to clear up this difficulty the instructor may produce a model as shown in the accompanying diagram. The materials required may be readily borrowed from the chemistry department so that no expense is connected with the demonstration. It will be observed that by opening or closing the screw clamps one may regulate the flow of current in any part of the circuit and that by proper adjustment no current will flow in the galvanometer circuit when the bridge is balanced. In order to enable one to follow the flow of current more readily it is desirable to introduce a number of air bubbles in the stream of water and for this purpose the filter pump will serve very well.



Wheatstone Bridge Model. Materials Required: 4 Screw Clamps, 2 Y-Tubes, 2 T-Tubes, 1 Filter Pump, 7 Pieces Rubber Tubing.

REPORT

of the

One Hundred Fourteenth Meeting

of

Eastern Association of Physics Teachers

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Cambridge, Mass.

SATURDAY, MARCH 8, 1930

OFFICERS FOR 1930-1931

President, Burton L. Cushing, Mechanic Arts High School, Boston, Mass.
Vice-President, Louis A. Wendelstein, High School, Everett, Mass.
Secretary, W. W. Obear, The High School, Somerville, Mass.
Treasurer, William F. Rice, Jamaica Plain High School, Boston, Mass.

MORNING PROGRAM

9:30 Meeting of the Executive Committee.

9:45 Business meeting.
- Annual Report of the Secretary.
- Annual Report of the Treasurer.
- Report of the Auditor.
- Report of the Nominating Committee.
- Election of Officers.
- Election of New Members.
- Reports of Committees.

10:30 Annual Address of the Vice-President: "Experiences in College Preparatory Physics Teaching." Frederick M. Boyce, Phillips Academy, Andover, Mass.

11:00 Address: "Present Inadequacies and Suggested Remedies in the Field of the Teaching of Physics." Dr. A. W. Hurd, Institute of School Experimentation, Teachers' College, Columbia University.

11:45 Demonstration of New Apparatus. Dr. Paul E. Klopsteg, Central Scientific Company, Chicago, Ill.

1:00 Lunch. The Members of the Association will be the Guests of the Institute in the North Dining Hall.

AFTERNOON PROGRAM

2:00 Address: "The Cyclical Nature of the Universe." Prof. Norman E. Gilbert, Dartmouth College, Hanover, New Hampshire.

3:00 Address: "Some Experiments in Physics Heat." Prof. Gordon B. Wilkes, Massachusetts Institute of Technology.

SECRETARY'S REPORT.

Our three meetings of the year have been held May 4, 1929, at Phillips Andover Academy; November 2, 1929, at Harvard University; and March 8, 1930, at Massachusetts Institute of Technology. The programs have been varied and full of interesting addresses and features. It is evident from the numbers present at the meetings that attendance is by no means limited to active members.

The marked innovation of the year has been the new arrangement for publishing reports of our meetings. Beginning with the 113th meeting, the reports will be printed in the magazine SCHOOL SCIENCE AND MATHEMATICS. Active members will receive all numbers of this magazine, and associate members will receive the numbers containing our reports. This arrangement is mutually advantageous to the magazine and to us. In order that it may work smoothly, however, it will necessitate prompt payment of all dues.

We have again this year lost by death two of our former officers, Mr. John W. Hutchins, and Mr. Irving H. Upton. Both had been long associated with us and had served us well. A more extended appreciation of these men appears later in the report of this meeting.

Our membership stands at active 85, associate 73, total 158. A study of the reports for the last ten years shows the number of active members has varied from a low of 70 to a high of 90, with an average of 81½. The total membership has varied from 146 to 159. Our membership numbers then are practically unchanged in the decade. Our cash reserve during the same time has increased from $283 to $480, showing that the present membership is large enough to sustain the financial burden of the organization. It is the opinion of the secretary, however, that we should have a much larger membership in order that the influence of the association may be extended, and that we may be of greater service in shaping the teaching of Physics in our New England schools and colleges.

Respectfully submitted, W. W. OBEAR.

REPORT OF THE TREASURER FOR 1929-30.

Receipts:			
Balance March, 1929			$479.07
Dues:	Active 1929-30	$228.00	
	Associate 1929-30	136.00	
Arrears:	Active 1926-29	45.00	
	Associate 1926-29	18.00	
Total dues		$427.00	
Interest		14.22	
Extra $1 from Associate members for full subscription to School Science		24.00	465.22
			$944,29
Expenditures:			
Printing		$251.96	
Postage and Stationery		27.21	
Expenses of Secretary and Treasurer		45.49	
Meetings		23.65	
School Science		246.00	594.31
Balance, March, 1930			$349.98
Expenses, 1929-1930			$594.31
Received, 1929-1930			465.22

Deficit	$129.09
In Jamaica Plain Trust Co.:	
Checking Account	$ 84.13
Savings Account, No. 16067	265.85
	$349.98

Respectfully submitted,
WM. F. RICE, Treasurer.

Examined and found correct, March 6, 1930.
F. E. MASON, Auditor.

The nominating committee, Mr. John B. Merrill, Chairman, Mr. Clarence M. Hall and Mr. Raymond S. Tobey presented the following candidates and they were elected to serve for the ensuing year:

President: Burton L. Cushing, Mechanic Arts High School, Boston.

Vice President: Louis A. Wendelstein, Everett High School.

Secretary: William W. Obear, Somerville High School

Treasurer: William F. Rice, Jamaica Plain High School, Boston.

Executive Committee: Elliott P. Frazier, English High School, Boston.

Ralph B. Delano, Memorial High School, Boston.

Lawrence A. Howard, East Boston High School.

President Hatch took this opportunity to thank the Association for the support given him during his administration.

The following committees have been appointed by the President for 1930-1931:

New Apparatus: John C. Packard, Brookline High School; Thomas A. Pickett, Mechanic Arts High School, Boston; Clarence W. Lombard, Hyde Park High School.

College Entrance Requirements: Frederick E. Sears, St. Paul's School, Concord, N. H.; Francis E. Mason, High School of Commerce, Boston; Raymond S. Tobey, Girls' Latin School, Boston.

Membership: Fred R. Miller, English High School, Boston; Homer W. Le Sourd, Milton Academy, Milton, Mass.; Roy R. Hatch, Mt. Hermon School, Mt. Hermon, Mass.

Current Events: Clarence M. Hall, Central High School, Springfield, Mass.; Daniel J. Shea, High School of Commerce, Boston, Mass.

Magazine Literature and New Books: Robert W. Perry, High School, Malden, Mass.; Arthur V. Donnellan, Jamaica Plain High School, Boston.

The following members were elected:

ACTIVE.

Robert Blair, High School, Malden, Mass.
John P. Brennan, High School, Provincetown, Mass.
John T. Gibbons, Brighton High School, Boston, Mass.
John J. Hopkins, Jamaica Plain High School, Boston, Mass.
Dr. Archer W. Hurd, Teachers College, Columbia University.

ASSOCIATE.

Franklin H. Reed, High School, Haverhill, Mass.

REPORT OF COMMITTEE ON MAGAZINE LITERATURE.

JAMES W. DYSON, *Chairman, Mechanic Arts High School, Boston.*

Journal of Chemical Education:

Jan. 1930, Page 109, The Lecture-Demonstration Method in the High School, Van Horne.

Feb. 1930, page 283, The Education of the Superior Student, J. J. Abel.

Mar. 1930, The Chemical Action of Light, Bodenstein.

Tycos:

Jan. 1930, page 13, Overcoming the Greatest Foe to Aviation, S. R. Winters.

Jan. 1930, page 23, Trips of the Carnegie, 110,000 mile cruise of non-magnetic ship.

Literary Digest:

A series of articles showing how common things work. Feb. 15, Vacuum cleaner. Feb. 22, Fireless cooker. Mar. 1, Meters.

Popular Science Monthly:

December, 1929, A New World Run by Dynamo.

January, 1930: The World Must Outlaw Noise. What Science Achieved in 1929. Keeping Pace With Aviation.

February, 1930, Now—The Automatic Pilot.

Scientific American:

December, 1929: An Office Building of the New Era. Television's Progress. Radio in 1930.

January, 1930: Details of Front-Drive Car. The Airplane Diesel in 1940. The Rarest Metal Yet Obtained.

February, 1930: Future Sources of Power. How Old is the Earth. New Methods of Attack. The Radio and the Spectroscope.

March, 1930: Power From the Heat of Arctic Waters. Our Eyes and the Movies. An Experiment in Suspended Gravitation.

REPORT OF CURRENT EVENTS COMMITTEE.

LOUIS A. WENDELSTEIN, *Chairman, Everett High School.*

LIGHT.

Dr. Elihu Thomson of the General Electric Company at Lynn, Mass., recently announced that success had been achieved in surmounting the first obstacle in the construction of a 200 inch reflector telescope, which will peer into space four times as far as man has ever looked before.

When work was begun a year ago, two methods were tried in making the smooth quartz glass surface; neither of these methods was successful. One method consisted of melting tiny bits of quartz, and the other, large slabs.

At the suggestion of a laboratory assistant a method similar to spraying paint on automobile bodies was tried,—and it proved successful. The quartz was ground to flour-like consistency and then run through a roaring blow-torch which sprayed it flaming at 3000 degrees upon the mirror backing of the reflector.

An oxy-hydrogen torch is used and in spraying the 200-inch reflector it is estimated enough hydrogen is utilized to float a Zeppelin. Thus far the largest mirrors made by this process are two feet in diameter. When the big one is made, it is predicted that field glasses will be used for observation to keep out of range of the withering heat.

The cost of the telescope is estimated at $6,000,000. The international board of education financed it for the California Institute

of Technology and the General Electric Company, of which Dr. Thomson is an official, is contributing the mirror work at cost.

Although only twice the diameter of the present largest telescope, the new mirror will collect four times as much light and is expected to "see" that much farther. The present limit is the distance light travels in about 150,000,000 years. Through all that vast distance telescopes bring into view whole island universes of stars, with great empty spaces between.

The new telescope may look far enough beyond to reach the mysterious limit of some sort required by the Einstein theory of relativity. Astronomers, however, do not expect to find the kind of tangible that can be seen or photographed. Instead they hope that the greater power of visibilty, both near and far, may help to learn more about the nature of the "curved space-time" that Einstein postulated. They are confident it will show a whole lot of other things.

Since the installation of the neon tower at Croydon Airport, London, early in 1924, neon light has been championed by many as the panacea for all difficulties due to flying in fog. On the other hand there are those who claim that neon light has no added value over ordinary lights for fog penetration. More or less elaborate tests, made by the Bureau of Standards, the Illuminating Engineering Society, and others, seem to agree on certain points.

The fact that red light penetrates fog and mist more easily than white light is an admitted scientific fact, although some scientists will explain the result by saying that the candlepower of penetration is the same but that the eye is more sensitive to the red rays and can see a much smaller candlepower of red light than it can of white light. By any explanation, the result is the same.

This is apparent to anyone who has admired the orange-red appearance of the setting sun on the western horizon. The color of the light that emanates from the sun is the same at the source at all hours of the day but as it sinks lower in the sky and the rays must pass through the mist and clouds that hover about the earth, only the red light rays of the sun are visible.

The question then arises as to what is the most effective way to produce a red aviation beacon to secure the utmost penetration of fog. It is possible, of course, to use the ordinary electric lamp with a red screen, but based on the wattage necessary per candlepower, it is not practical when compared with neon light, which is more economical. The use of a colored screen cuts down the candlepower of the lamp, as from ⅓ to ⅚ of the original light is absorbed by the filter and wasted.

Electrified neon gas gives forth a natural orange-red glow at the cost of only ½ watt for each horizontal candlepower; in fact along the German air routes it is reported that neon course lights have been allowed to operate 24 hours a day because of their economy of electric current.

The fact remains that those airdomes that have installed fog-penetrating beacons with any degree of success have utilized neon tubes. The neon tower at Croydon has become famous. One pilot flying over France 100 miles away reported having seen it.

The neon beacon has another advantage in that its light is a peculiar shade of orange-red which is easily distinguished from other lights. Also, it has good visibility in clear weather.

ELECTRICITY.

One of the problems of aviation instrument engineering is to devise an altimeter that is at once more sensitive and more accurate than present instruments. In order to depart from the limitations imposed by the ordinary altimeter that works by air pressure, engineers have experimented with three methods: the acoustic method, in which the time for the reflection of sound from the ground serves to give height; the capacity method in which two plates on a plane serve as a condenser whose capacity is varied by approach towards the ground; and finally the radio method now being developed by Dr. I. F. W. Alexanderson of the General Electric Company.

A radio wave travels so fast that the time of its reflection from the ground is infinitesimal and cannot be made to give a measure of the height. An indirect method, however, has given positive results.

An oscillating tube circuit is used, one of the type which sends out a wave which may be picked up on other receivers as a squealing note or beat. The echo or reflected signal is picked up on the same set as that which sends out the wave. Every time the airplane changes altitude by half a wavelength, a whistling note goes through a complete tone cycle from low pitch to high pitch and back again. By counting the cycles of the tone, using half the wavelength of the oscillator as a measuring stick, it is possible to measure the altitude. By means of the meter, graduated from 3,000 to 200 feet, the pilot may read his altitude within close limits at any time. The "echoes" indicating height are periodic, becoming stronger as the plane approaches the ground. The periodic characteristics of the echo, and the chance that the pilot would not see the instrument at the instant an echo was recorded, presented a problem which was met by developing a "memory meter." In this instrument the echo is recorded as altitude when it occurs and the meter continues to hold that reading until a stronger echo, indicating a lower altitude, occurs. In approaching the earth, the memory meter gives a continuous indication of altitude.

A new lighting system designed to give shadowless illumination for surgical work of all kinds has been invented by Dr. Leon Lazar, a New York dental surgeon. It has been tested and approved by the United States Navy Department at Washington, D. C., and has been adopted by several hospitals and many dentists in New York City.

For dental work the instrument is mounted on a wall bracket or a floor stand, or may be attached to an extension of the dental chair. It includes three independent sources of direct light, each projecting an intense beam. These beams may be converged simultaneously to any focal point by means of a single control handle, which also regulates the horizontal and vertical movements of the instrument as a whole. The three circles of light thus superimposed upon each other illuminate the entire mouth without shadows, while their angle of direction protects the patient's eyes from glare. If one of the beams is obstructed by the dentist's body, the other two would still give shadowless illumination. A daylight filter to convert the intense artificial light to natural light, in which colors appear in their proper values, is a necessary adjunct for matching teeth, porcelain fillings, and the like.

The model intended for use in the operating rooms of hospitals is even more elaborate, involving eight light sources combined in a

single ceiling fixture that throws a seventeen-inch arc upon the operating table. The cumulative patch of light thus produced is adjusted by means of a single control handle. General illumination for the operating room is radiated from the same fixture.

When a small brass tube of radium, valued at $4,000, disappeared from a Los Angeles hospital recently, experts who were put on its trail borrowed an electroscope from the California Institute of Technology to help them find it. The electroscope consists of two hairlike quartz fibers wrapped with platinum in a container under a high pressure and charged with electricity from a dry cell. The emanations from radium discharge an electroscope and allow the fibers to come together.

The search began in the room where the radium was last seen. There the electroscope's fibers wavered slightly. The lost mineral's route was traced through the hospital and the grounds to the incinerator. But it had left the incinerator. Apparently it had gone to the city dump, so the tracers went there. At the dump the fibers of the electroscope drew together, and the radium was found.

Mechanics.

A new way to make the earth time its own rotation, as though a foot racer carried a stop watch to time himself, has been devised by Captain Frank B. Littell and J. E. Willis, of the United States Naval Observatory, in Washington.

The earth's rotation is taken by all scientific men as a fundamental standard of time. By it are regulated the clocks of all civilized countries. To make sure that the astronomical clocks which keep this world time are always correct, they are checked at intervals by observing the apparent motion of the stars. From the instant a star passes precisely above an astronomical observatory tonight until the instant that same star passes overhead tomorrow night is precisely one day.

Usually this fundamental time unit is measured by a human eye. Looking through a telescope pointed directly overhead, an astronomer observes the instant at which the image of a selected star passes across a fine spider web inside the telescope. At that instant the astronomer presses a button which serves to check the error, if any, of the observatory's clocks. One difficulty of this method is the introduction of what is called the "personal error"; due largely to the time which the astronomer needs to see the coincidence of star and spider web and to work the muscles necessary to press the signal button.

To avoid such errors the Washington astronomers have devised their new method. Installed in Washington is a special telescope called a Ross Reflex Photographic Zenith Tube. Light rays from stars almost directly overhead enter this vertical tube through a lens and strike a surface of metallic mercury at the tube's bottom. Thence they are reflected to a photographic plate. As the whole tube turns with the rotation of the earth, star images make tracks across this photographic plate.

Captain Littell and Willis have attached to this Ross telescope devices by which each tick of the osbervatory's clock moves the photographic plate of the telescope a trifle. Thus the trail made by a passing star consists of a series of dots or dashes on the plate, not a continuous line. Just before the selected star is to pass directly overhead, the position of the photographic plate is changed. Two

lines of dots or dashes are thus produced, one for the star trail before the change of plate position, the other for the star trail afterward. By measurement and computation of these, the astronomers determine the precise fraction of a clock-tick at which the star was exactly vertical.

Development of a new metal known as Konel, which is credited with being much stronger than other metals at high temperatures and which can be used extensively in the moving parts of internal combustion engines and other extremely hot places, has been announced by officials of the Westinghouse Electric and Manufacturing Company. The announcement followed the granting of foreign patent rights.

Originally developed by the Westinghouse Research Laboratories as a substitute for platinum in the manufacture of filaments for radio tubes, the new metal was discovered to be harder to forge than steel, and to be very tough at high temperatures, when most metals lose their strength. Engineers predict many uses for Konel. The new metal was created by Dr. E. F. Lowry, a graduate of Ohio State University.

Dr. Lowry said Konel had been subjected to exhaustive tests which revealed in turn the many valuable qualities it possessed.

"Almost without exception metals grow softer and lose tensile strength as they undergo high heat," he said. "We have found that Konel, heated to 600 degrees, Centigrade, which is approximately 1100 degrees, Fahrenheit, will withstand a pressure of 60,000 pounds to the square inch. Even further tests show Konel is tougher and harder when heated to 1800 degrees, Fahrenheit."

Dr. Lowry explained that Konel is a combination of cobalt and nickel from which it derives its name, and ferrotitanium.

As a substitute of platinum, Westinghouse officials are authority for the statement that Konel already is saving approximately 250,000 dollars monthly in the manufacture of radio tubes. Platinum costs approximately 180 dollars per ounce, while the new susbtance costs only a few dollars a pound. Life of Konel filaments is approximately 10 times longer than that of other filaments. Tubes with filaments made of the new metal are operated 175 degrees colder than tubes with platinum filaments but with the same emission, thereby giving better reception results, research engineers say.

IN MEMORIAM.

The following memorial sketches of two of our former officers were presented by the committees which had been appointed to prepare them:

John Wesley Hutchins. 1856-1930.

John Wesley Hutchins was born in Dover, New Hampshire, seventy-three years ago. After attending the local public schools he entered Bates College and graduated in the class of 1878. A few years later secured his Master's degree from the same institution. While in college he attained highest honors in Mathematics, and participated in sports and other activities outside the curriculum. During the next ten years he was principal of Lebanon Academy in Maine, and of the high schools at Barnstable and East Bridgewater in Massachusetts.

In 1888 he came to the Malden High School as sub-master and teacher of Mathematics and Chemistry, and in 1897 was elected principal, holding the office for twelve years. During this period the school expanded rapidly and two extensive additions were made to the building. On each of these occasions he was able to secure unusually generous appropriations for laboratories and science equipment. The scholarship reputation of the Malden High School was never higher than during the principalship of Mr. Hutchins. In athletics his interest is shown by the fact that for twenty years and up to the day of his death he was secretary of the High School Principals' Association of Massachusetts, an organization which virtually controls the standards of eligibility in athletics.

From 1929 until his retirement in 1927 he enjoyed a long and honorable career as head of the science department and teacher of physics at the same school, and when the Malden High School chapter of the National Honor Society was formed it was given his name. His death came unexpectedly as the result of a heart attack on January 15, 1930.

For six years Mr. Hutchins was a College Board reader in Physics. In that group he was highly respected for his careful work. It was a common thing for him to follow painstakingly through a maze of figures in order to discover just what the student had done. It often happened that what at first glance appeared to be entirely wrong was in reality a correct and ingenious solution and that the only error was some slight numerical mistake. He was equally keen in detecting bluffs and fraudulent solutions. Thus the interests of the student and the college were both carefully guarded.

Mr. Hutchins was one of a small group of eighteen men who met at the Hotel Thorndike in 1895 to consider the organization of a club for the improvement of the teaching of physics. From this meeting came the Eastern Association of Physics Teachers, the parent of teachers organizations for a similar purpose throughout the country. Mr. Hutchins was very active in this association from the start and was its secretary in 1897, '98 and '99 and its president in 1900. Since that time he has served on many important committees, often as chairman, always as a worker. He was largely responsible for the compilation and publishing of a twenty-five page pamphlet entitled "A Descriptive List of Reference Books Suitable for Use in Secondary Schools." This was issued by the Association in 1900. So great was the country wide demand for copies of this pamphlet that in 1907, also under the leadership of Mr. Hutchins, it was revised and enlarged to fifty pages.

For thirty-five years no member of the Physics Association was more regular in attendance than Mr. Hutchins. He rarely missed a meeting and usually had something useful to contribute, either in open meeting or informally before or after the meeting. Since his retirement he has continued his membership and has shown the same interest as formerly. It goes without saying that we shall miss him for some time to come, and that his influence has had a permanent effect upon the teaching of physics.

For the Eastern Association of Physics Teachers,

FRED R. MILLER,
LAURENCE R. ATWOOD,
H. D. HATCH.

Irving H. Upton. 1862-1929.

Mr. Irving H. Upton of Memorial High School, Boston, died very suddenly on October 24, 1929, after giving thirty-three years of service to the Boston Public Schools. He was a "masterly teacher," companionable associate, gracious gentleman, devoted friend.

He was always ready to give freely of his time in order that he might be of assistance to those who were in need of help. The community in which he lived was a better community because he formed a part of it. All those who knew him will miss him greatly.

Mr. Upton was born in North Reading, Massachusetts, on September 22, 1862. He graduated from Phillips Academy at Andover in 1881 and from Amherst College in 1885. He continued his studies at Amherst until he received an M. A. degree. He taught school in Cotuit and Bradford, Massachusetts. While he was principal of the Portsmouth High School he took the Boston School Examinations and came to Roxbury in October, 1896. He was at one time president of our Association.

For all the help and inspiration that he gave to us as individuals and as members of this organization, we, the members of the Eastern Association of Physics Teachers, wish to honor his memory and pay tribute to his life and service.

For the Eastern Association of Physics Teachers,
R. B. DELANO,
JOHN B. MERRILL,
FRANCIS E. MASON.

It was voted that these memorials be spread upon the records and that copies be sent to the nearest members of the families of the deceased and also to the school papers.

Mr. Le Sourd, who has recently accepted an appointment on the staff of SCHOOL SCIENCE AND MATHEMATICS, expressed his desire to be used as the representative of the Association and asked for suggestions and contributions.

GREETINGS BY PROFESSOR NORTON.

Prof. Charles L. Norton, Head of the Physics Department of the Massachusetts Institute of Technology, through whose courtesy we enjoyed the facilities for this meeting, was present for a short time and spoke words of greeting and welcome. He also expressed appreciation of the work of the teachers of Physics in preparatory schools.

ADDRESS BY THE VICE-PRESIDENT

Annual address of the Vice-President: "Experience in College Preparatory Physics Teaching." Frederick M. Boyce, Phillips Academy, Andover, Mass.

This was an informal presentation of the subject from the point of view of a teacher of boys in a private preparatory school. Mr. Boyce called attention to the fact that all of the boys were preparing for college and that the problem of arousing interest is not a paramount one. He tries to teach them to think and emphasizes laws and facts. The talk was illustrated by many incidents drawn from his teaching experience in both class and laboratory.

PRESENT INADEQUACIES AND SUGGESTED REMEDIES IN THE TEACHING OF PHYSICS.

By Dr. A. W. Hurd,

Institute of School Experimentation, Teachers' College, Columbia University.

The progressive teacher is always cognizant of inadequacies in present instruction and is looking confidently forward toward improved materials and methods. While it may be worthwhile occasionally to look behind to see what progress has been made in past years in order to keep up one's courage, ultimate progress is dependent on keeping one's mind set on an ever upward goal. Absolute contentment does not carry one forward. Divine discontent is the talisman of progress.

A logical progressive program takes stock of present attainments, analyzes inadequacies, and plans for remedies to overcome or alleviate the inadequacies. Why, then, is there need for reorganization in the teaching of physics?

A first answer is that discoveries in physical science are rapidly changing the content of physics. The great advances in this field have received such constant mention that they need not be dwelt upon here. To my mind, these discoveries will in the nature of things, find their several ways into the curriculum. This is inevitable and may be depended upon to take care of itself.

A second, and perhaps less well understood reason for reorganization lies in the discoveries of educational investigations. These have served to turn the attention of educators upon the unit of instruction—the individual pupil. The development of individuals is the goal of the school and a first and foremost consideration for the teacher. The ultimate success of the pupil as a healthy contributing member of society is the objective which needs continual emphasis.

A third reason for reorganization follows immediately from this, viz., that the school population is quite different from that of a few years ago. Whereas when only those pupils who cared to attend high school did so, now, on account of compulsory educational laws and educational propaganda, large proportions of our population up to 18 years of age are actually attending. The problems of instruc-

tion have, therefore, changed. Educational facts have shown that the school population of a single class is of tremendous variety. It may be interesting to note these variations in some of my own classes in high school physics in 1925. The data were collected in preparation for an experiment in the second semester of a year's course in physics. This experiment had for its purpose the discovery of a plan of instruction based on the needs of the individuals in the class. Before planning a course to fit the needs of individuals, it was thought logical to make a survey of the pupils in order to better judge their needs.

A picture of these classes of 83 pupils shows the following: (1) a range of intelligence quotients from 80 to 129, with a median of 109; (2) a range in a preliminary prognosis test, constructed by the instructor, from 0 to 29, with a median of 21.9; (3) a range of chronological age from 14 to 19 years; (4) 59 boys and 24 girls; (5) a range of teachers' marks in past courses in mathematics from D to A; 24 having D's, 18—C's, 17—B's, and 6—A's; (6) a wide range of teachers' marks in the character traits of industry, initiative, reliability, and punctuality; (7) a range in classes in school from 10 A to 12 A; (8) 25 of the group regularly taking music or other lessons outside of school hours; (9) 21 regularly employed every day outside of school hours; (10) 47 having regular daily home duties requiring a minimum of one hour; (11) 49 not having had general science, 62 not having had biology, 66 not having had botany, and 73 not having had chemistry—meaning that there were a good many who had taken these courses; (12) 21 having had one science previously, 13 having had two, 6 having had three, 1 having had four, and 31 having had none; (13) 41 definitely planning to go to some university, college, or normal school, and 27 undecided; (14) 22 occupational first choices represented, the highest number being 13 for pharmacy, the second 12 for engineering, with the others widely scattered; (15) 50 occupational choices mentioned in all first, second, and third choices; (16) expressed interest in physics from "rather dislike" to "like very much"; (It might be well to say that the designations used were dislike very much, dislike, neither like nor dislike, like, like very much, constituting 5 choices) ; (17) expressed interest in mathematics from "dislike very much"

to "like very much"; (18) similarly expressed interests in general reading, and in using tools; (19) 13 with no hobbies to 25 hobbies of all sorts and descriptions; (20) 56 occupations of parents of pupils included; (21) 28 having parents who had graduated only from grade school, 10 who had graduated from high school, 5 from college, 2 from normal school, and 31 from no school; (22) a range of scores in a preliminary information test in the subject from 10 to 69, with a median score of 34.9.

The only excuse for offering a *fixed course* to such *varied* and *heterogeneous* groups is that training in one field transfers to all other fields and this has been proven untrue. Because a person develops specific abilities in one field, it does not follow that he develops at the same time appreciable abilities in unrelated fields. In other words, educational studies have shown quite conclusively that the primary reason for taking a given course should be that it develops specific abilities which the student needs, i. e., he must be interested in it for its own sake. In a *flexible course in physics*, on the other hand, there are phases which are of interest to anyone who cares to enroll. There are, on the other hand, phases which are of interest to few. The individual pupil has a choice in the matter.

The reasons for the desirability of reorganization are then (1) changes in the science of physics, (2) changes in the general objectives of education directing attention to the development of individuals as the purpose of the school, and (3) changes in the school population.

What procedures should be followed in reorganization? A survey of the literature written from 1900 to 1926 on the teaching of physics may indicate some of the points of emphasis.

One purpose of the survey was to discover a consensus of opinion on the subject of inadequacies in the teaching of physics, if there were any. It was the only available substitute for calling together a great many representative teachers from all over the country in order to agree, if possible, on outstanding needs in the teaching of physics. The survey consisted of making notes of pertinent statements by these writers, and including together those which were similar to form categories representing a consensus. Alto-

gether more than 85 separate books or periodical articles were consulted, some of these being reports of committees or commissions consisting of many persons. The following are representative of the statements appearing on the tally sheets: Lesson assignment from text inexcusable; lack of a few accepted common aims; content too bulky; too abstract, mathematical, specialized; subject matter should be adapted to individuals; teachers need more definite training for the job; problems too detached from life; too much mechanics; a few well chosen problems; change to meet modern needs; relate subject matter to life; better methods; pupils should not be trained for physicists; too much notebook work; too minute directions; too much authority; better methods of measuring achievement; research on teaching methods and materials; aggregate boys and girls; too much laboratory; too little demonstration; make pupil surveys; too much college oversight; need new texts; too loose use of terms; library in room; etc.

The analysis of this literature resulted in the following summaries in order of importance: (1) the greatest need at present is a reorganization based on a more careful selection of subject material or content to meet the needs of the pupils in the class (64 per cent of all statements); (2) we need better teachers trained in the science of child development (13 per cent of all statements); (3) we need more carefully defined objectives of instruction (8 per cent of all statements); (4) there should be greater flexibility in our courses with attendant responsibility and freedom of action of pupils (7 per cent of all statements); (5) educational science (the scientific method) should dictate future changes in the course (7 per cent of all statements).

These statements have been guiding principles for a plan carried on ever since 1926 and the constant task has been that of working out a course in physics along lines suggested by these summaries.

A brief account of some work done in the last three years may be interesting and suggestive. Some of this work has been carried on as a member of the Committee on the Development of Standards for Use in the Reorganization of Secondary School Curricula of the North Central Association of Colleges and Secondary Schools, and chairman of the sub-committee on physics.

The four ultimate objectives of the committee, which are condensations of the seven cardinal principles, have been adopted and used in the selection of content as well as could be determined by individual judgment. They are:

(1) The health objective, (2) the vocational objective, (3) the avocational objective, and (4) the social objective. In brief, this means that every part of the proposed course in physics has been selected because it contributes directly or indirectly to one or more of these four objectives.

The immediate objectives of the committee are of four kinds or descriptions, viz., (1) knowledge, (2) appreciations or attitudes, (3) techniques, and (4) habits and skills. The thesis accepted is that the course in physics or any other subject should be developed so as to contribute eventually to the four ultimate objectives by means of the four kinds of immediate objectives.

This seems radical at first glance and yet no sound arguments can be advanced against it. The only argument which has been advanced to my knowledge, is that these objectives cannot help us much in the development of science courses—which, of course, is no argument at all. It would probably be more acceptable to say that if parts of the science of physics cannot be made to contribute to one or more of the ultimate and immediate objectives, it has no place in a high school curriculum. The immediate task seems to be to select those portions which unmistakably do so contribute. There is no doubt but that all portions can be shown to so contribute for some one individual, at least.

The sub-committee on physics has attempted to formulate a course in keeping with these objectives by the following plan: (1) divide the course into *natural teaching units* around *applications of physical principles;* (2) select ultimate objectives for each unit, which the unit may most naturally be planned to accomplish; (3) include in each unit outline (a) a list of common activities for all pupils (minimal essentials), (b) a list of supplementary *suggestive* activities for capable pupils (to care for individual differences), (c) a list of suggested reference books for pupil use; (4) prepare a preliminary test for each unit to measure, at least roughly, *knowledge, techniques, attitudes,* and *habits and skills;* (5) prepare similarly a final test. A fur-

ther premise is that all units shall be considered tentative, and that changes shall be determined by, and based upon, objective data obtained from the use of the units under experimental conditions. It may be well to add that the units constitute enough of the materials thought of as conventional physics to satisfy requirements likely to be made by any state or college board.

The unit titles selected are as follows:

Unit I—Hydrometers as illustrative of the applications of the principles and methods of science.

Unit II—What are machines and of what value are they?

Unit III—Principles of liquid and gas pressure and their applications in water and gas supply systems.

Unit IV—Applications of the principles of fluid pressure in water and air craft.

Unit V—Heating, ventilating, and humidifying systems.

Unit VI—Refrigeration and other applications of heat energy.

Unit VII—Atmospheric electricity and some of its manifestations.

Unit VIII—Electric lighting systems.

Unit IX—Electric generation and transmission.

Unit X—Electricity in communication.

Unit XI—Electro-chemistry and the storage battery.

Unit XII—Photography and picture projection.

Unit XIII—Telescopes and microscopes.

Unit XIV—Light projectors.

Unit XV—Color and some of its phenomena.

Unit XVI—Musical instruments.

Unit XVII—X-rays and other radiations.

Unit XVIII—Simple manifestations of gravity.

Unit XIX—The automobile.

These titles suggest at once daily life applications. It is probable that most high school pupils are interested primarily in things in the environment rather than in abstract principles. Or, stated slightly differently, they are interested in principles only as they are very evidently useful in helping them understand their physical environment. This plan is based on that assumption.

During the school year 1928-29, twelve of these units were given experimental "try-outs" with 34 groups of pupils

ranging in number from 14 to 74, enrolled in from 1 to 11 classes in 6 different schools. Pupils per test ranged from 30 to 265.

An educational research man is intensely interested in educational facts. Science is classification of knowledge which is fundamentally dependent upon the discovery of relationships among facts. The science of education is now in the first stage, or that of fact gathering.

The facts obtained from these experiments are as follows:

1. There is clear evidence of gain by every pupil in every group using a unit. The mean gain per group per test is about 33 per cent; the mean final score about 50 per cent.

2. There is evidence that pupils and groups of pupils vary considerably in the *gains* shown, as well as in scores on the *preliminary* and *final* tests.

3. There is evidence that achievement is less than that commonly supposed. The percentages given in (1) substantiate this statement.

4. There is evidence that pupils tend to have greater ranges of ability after instruction than before. In other words, instruction as carried on has not made pupils more alike, but more unlike. While all have shown measurable gains in ability, the variabilities about the respective group levels are greater after than before instruction.

5. There is some evidence that pupils who have had general science have higher achievement ratings in certain fields, notably electric lighting, and heating, ventilating, and humidifying. In fields more unrelated to general science, there is practically no indication of superiority.

6. There is evidence to show that juniors do as well as seniors in physics if the course is a junior course.

7. There is overwhelming evidence that the present year's course in physics contains too much content if greater achievement is to be expected. There is not time for more than 12 of the 19 units given above, if standards so far reached are to be maintained. The present conventional content would require all 19. The apparent alternatives are (1) more time, (2) less content, (3) possible improved means of instruction.

At the present time, at the Institute of School Experimentation, we are carrying on more than 50 experimental

"try-outs" of these units. In addition there are seven control experiments under way, the purpose of which is ultimately to find if possible a *better* or *best* method. The data collected will be used to further improve teaching in physical science. It is believed that through such cooperative experimentation, progress will be most wisely directed and secured.

A LECTURE DEMONSTRATION OF NEW APPARATUS.*

By Dr. Paul E. Klopsteg,
Central Scientific Company, Chicago, Ill.

The development of physical apparatus for educational purposes has a fascination that few other activities afford. I consider very fortunate indeed, those of us whose life work has taken its path into this field. Not only is the work interesting in itself, but it is work which offers a challenge to one's understanding of physics, and one's ingenuity in applying it, and it shows very tangible results and obvious benefits. Teachers who have struggled along for years with misfit equipment will require no argument to convince them that there is much room for improvement; and those who know the thrill that comes from success in creative effort will realize the enthusiasm with which we carry on these activities in our laboratories.

Our work in part is directed toward embodying good ideas for instructional apparatus in new designs, some of which I am permitted to show you. It is astonishing what a vast number of excellent ideas are buried in both European and American scientific journals. We have found great stimulation in the reading of such accounts, and to them we are indebted, in many instances, to the initiation of a development which has resulted in a very excellent apparatus. During the years that it has been my privilege to work in this field, I have become greatly impressed with the fact that there are really very few new ideas for apparatus. We have repeatedly found, when a suggestion was submitted, that the same or a very similar suggestion appeared in one of the journals anywhere from 10 to 40 years ago. As a general rule it must be

*The experiments described in this lecture were fully demonstrated but lack of space prevents publication of photographs of the apparatus used.—Ed.

said, then, that the greatest novelty in a new apparatus is the manner in which the scientific principles have been combined in it, and the features of mechanical design.

This question of design is perhaps of greater importance to the user than he may realize when he receives a finished apparatus ready for his use. Certain small mechanical features which look exceedingly simple and which you feel should have been obvious, may have required many hours of brain-wracking on the part of the designer. You bless an apparatus that remains unobtrusive because it is well behaved and requires no special attention, and nevertheless keeps functioning year after year. You do the opposite when you encounter a piece which, because of faulty design or construction, is in constant need of attention. You have the right to expect that apparatus should above all embody correct scientific principles, and that it shall be of such mechanical excellence and finish that it will give the kind of service that will keep it from coming to your attention for reasons which are annoying to you. That is the kind of apparatus which we are endeavoring to develop in our laboratories and to build in our shops. I very greatly appreciate the opportunity of giving you demonstrations of some of the recent results of that development work.

Experiment I—Spark Recording in Acceleration Experiments.

The problem of recording instantaneous positions of a moving body in accelerated motion has usually been solved more or less unsatisfactorily by using a tuning fork and tracing a wavy line on a smoked or otherwise prepared surface which moves relatively to the fork. The fundamental objection to this method is that the student is unable to verify the value given him as the frequency of the fork, and there must be left in his mind some doubt as to the accuracy of this figure. All of you probably know that his doubt is very well founded. Not only is the frequency of the fork a somewhat uncertain quantity, but it is subject to great errors when the prong carries a stylus which scrapes over a surface. The counting of waves in the tracing of the fork is a time-consuming and certainly uninteresting job, and we must remember that

the purpose of counting is simply to obtain a time interval sufficiently long to be easily handled in the data and computations.

In the apparatus we have worked out a method of recording instantaneous positions of a moving body by means of a series of equally timed sparks from an induction coil. One of the most interesting applications of this method is in connection with a freely falling body as we have developed it in the so-called Behr apparatus. Unfortunately, I am unable to show you that, but I have here another more easily portable form of acceleration apparatus which will show quite clearly how the record is timed. I wish to emphasize that the recording apparatus is one that has many uses. We have developed at least five applications of spark recording, ready for use in the laboratory, and others suggest themselves as need for them appears.

One of the outstanding advantages of this method is that the student can determine for himself with great accuracy the length of interval used in his computations. It is so simple that he has no difficulty understanding how such a short interval can be accurately measured. The record which he makes in the experiment becomes part of his report. There is great saving in time, both in the use of the apparatus and in the reduction of the record strip to numerical data on the basis of which he computes the acceleration. Observation of the motion while the record is being made gives him a clear idea of what is implied in the term "acceleration," and the record on the strip gives him a graphic picture of such motion.

Experiment II—The Impulse Counter.

The application of this interesting device is counting the number of vibrations of the bar on the spark timer. It was originally designed for that particular purpose. We soon found, in experimenting with it, that its applications were much wider than merely this one use.

In trying to get an idea of the frequency range within which the counter would respond, we were astonished to find that it would function reliably at any frequency up to 120 per second, provided the power supply was suitably adjusted. It has counted impulses of even greater

frequency than this, but we do not recommend it for the higher frequencies. The fact that it responds as it does permits it to be used with a step-down transformer on an alternating current lighting circuit. Since an electromagnet is used for actuating the mechanism, it counts alternations rather than cycles.

One interesting experiment in which it may be used is that of setting an iron wire in vibration with an electromagnet supplied with alternating current and adjusting the tension on the wire until resonance is obtained. The frequency of the current which maintains the wire in vibration can then be directly determined with the impulse counter.

Another experiment which can be performed with this counter is to provide such a vibrating wire with a light contact point and a mercury cup, so that the circuit may be interrupted at each complete vibration. The impulse counter can then be used for measuring the number of vibrations per second, and the well known formula for the frequency of a vibrating string can thus be verified.

Still another application of the impulse counter is its use as a high speed stop watch. You have seen that the counter operates 120 times per second when it is connected to an alternating current line with controlled frequency such as we have on most of the large power systems today. It becomes a stop watch which shows 1/120 of a second. This is too high for ordinary physical experiments, but for psychological experiments, for measurement of reaction time, for example, it is quite satisfactory. To use it as a stop watch of lower speed, the bar on the spark timer can be adjusted to any desired frequency below 27 per second. If it is adjusted to 20 per second, for example, the impulse counter connected to it becomes an excellent stop watch indicating to 1/20 second, for measuring the duration of short events. Its accuracy can always be checked by means of a good watch.

One of the very interesting applications of the impulse counter which came to light recently is its use in determining the frequency of heart beat of the ordinary house wren. I cannot give you the details of the arrangement beyond saying that a perch is provided for the wren,

which is supported by a device like a phonograph pickup. When the wren sits on the perch, it produces voltage impulses of the frequency of its heart beat, which are then amplified, and by means of which the impulse counter is operated.

The counter has also been applied to the counting of the number of alpha particles coming from a radioactive material with the help of a Geiger counter.

Experiment III—Flettner Rotor Ship Model.

In this experiment you will note a dual use for a single piece of apparatus, namely, the miniature railroad track used in our first experiment. In fact, we have four experiments worked out for it. One of our efforts during the past few years has been to develop as many uses as possible for a single piece.

This demonstration is intended to show the principle of the Flettner Rotor Ship, which principle is known as the Magnus effect. The rotor is mounted on a car that runs on the railroad track. To prove to the student that there is no concealed mechanism in the car which drives it along the track, we designed the rotor to be spun like a gyroscope. An electric fan is needed in this experiment, the current of air from which combines with the air sheet dragged around by the rotor to produce force in the direction of the track. Whether the force is toward the right or the left depends, as you know, upon the relative directions of the air current and rotation of the rotor.

Experiment IV—Apparatus for Composition and Resolution of Forces.

The very simple apparatus for an experimental study of composition and resolution of forces was developed in response to a need which we sensed for something much simpler than the time-honored force board. An additional requirement, and an important one, was that of its occupying small storage space. The three arms of the apparatus can be set at any desired angle, each relative to the others, and the force exerted by each spring balance can be adjusted by lengthening or shortening the cord which is connected to the central ring. This lengthening or shortening is accomplished by a small Bakelite piece fashioned after the well-known tent-rope tightener.

You will notice that the number of combinations of forces and angles is unlimited. When a balance of the forces has been established by the centering of the ring about the central peg, the student places the apparatus on a sheet of paper and draws lines along the beveled edge of the slot in each of the three arms. He also records on the paper the reading of the spring balance corresponding to each of the three lines. This constitutes the record of his experiment and he may proceed to solve the parallelogram or the vector diagram of the forces graphically or by trigonometry. When the apparatus is to be stored, it is simply folded together, and when folded, occupies very little space.

EXPERIMENT V—LINEAR EXPANSION APPARATUS.

Much ingenuity has been applied to apparatus for showing the expansion of metals. As a specimen of the metal a rod or tube is usually used. Most of the apparatus of this kind requires a source of steam for heating the specimen. It was my intention in working out the apparatus which is to be demonstrated next, to heat the sample electrically. This suggested that a wire through which a current might be passed, would constitute a very suitable specimen. With the present apparatus we are able to show very small changes of dimension of the wire qualitatively by motion of a large pointer over a large scale. We are also able to make very rapid measurements of the quantities necessary for calculating the coefficient of linear expansion of the wire used as the sample in the apparatus.

My source of current for heating the specimens of wire is a 6 volt storage battery. Between the battery and the linear expansion apparatus I have inserted a carbon compression rheostat of rather novel design, which I shall take a moment to describe.

The ordinary form of carbon rheostat has a range of about 5 ohms with a minimum value of perhaps a few hundredths of an ohm. We recognized the excellent features of a rheostat of this type, but felt the serious limitation of range. One reason for this limitation is the fact that the pile of carbon plates is not resilient and consequently it does not follow the clamping screw through

a distance greater than about two-thirds of one turn of the screw. Another limitation which was discovered in our analysis of this useful device, appeared to be that it could not dissipate great quantities of heat. We therefore set about correcting the situation in the following manner:

We have punched out a large number of thin metal plates which are slightly bent so as to be resilient. Each of these metal plates is as wide as the side dimension of one of the square carbon plates, but its length is about 50% greater. By inserting one of these thin metal plates between adjacent carbon plates throughout the length of the carbon pile, the shortcomings of the carbon rheostat are overcome. The composite pile is now so resilient that it follows the screw through eight complete turns, and its resistance range is increased to about 50 ohms. Aside from resistance change due to temperature changes, the resistance remains steady at any setting. The metal plates also conduct the heat out from the carbon pile, and they are so arranged that air passing upward between them carries off the heat quickly. As a result the watt capacity of this useful laboratory device has been doubled for the same temperature rise.

Coming back now to the linear expansion apparatus, you notice first that when a current is sent through the wire, the pointer moves. This is the qualitative experiment showing linear expansion of the wire as it is heated. To render the experiment quantitative, that is, to make a measurement of the expansion coefficient, we must know two temperatures between which the change in length takes place. We must also know the length of the wire and the amount of its expansion. The wire at present in the apparatus is one of brass; three or four different kinds are supplied.

We puzzled for a long time over a suitable method of finding the two temperatures. Since it is a demonstration, we did not feel that great accuracy was an essential requirement. We therefore adopted room temperature as the lower value. The higher temperature value at which the wire was to be heated, gave more difficulty. We finally hit upon a very successful indicator after trying thermally sensitive paints and other means. We suspend a small weight from the wire by means of a narrow

strip of pure tin foil. Such a strip is conveniently cut from tin foil by means of a straight edge and a razor blade. We next note the zero reading of the apparatus which corresponds to room temperature. We then pass a current through the wire, and if the temperature rises the pointer moves upward along the scale. At the instant the melting point of tin is reached, the weight drops and we read the scale again. Since the scale readings are purely arbitrary, it is necessary to interpret them in millimeters or centimeters. The screw adjustment for the wire is, at the same time, a micrometer screw having a pitch of 1 mm. We can therefore easily calibrate the scale since all that is required is to turn this screw through one complete revolution and obtain the scale reading at each of the two pointer settings.

The only thing left to measure is the length of the wire, which is easily done. In an experiment performed before this demonstration, we found that the pointer moved over 7.6 of the figured scale divisions. The melting point of tin is 232° C. and the room temperature was 22°C., so that the change mentioned above was that corresponding to a temperature rise of 210° C. Turning the micrometer screw through 1 revolution gives a scale calibration of 7.4 figured divisions per mm. The length of the wire is 25 centimeters. The calculation made in the usual way gives a value of 19.5 parts per million as the expansion coefficient of brass. Published tables give values from 18.8 to 20, depending on the kind of alloy composing the brass.

This apparatus is also well suited for showing in a most striking manner the transformation points of steel. I insert a steel wire in place of the brass wire and use a sufficiently large current to bring the wire up to red heat. You notice that the total expansion for this temperature change is much greater than the range of the scale. We therefore start the pointer at a very much suppressed zero position, and as the temperature of the steel wire reaches redness, we note that the pointer pauses and may actually move backwards for a small distance, before it resumes its upward travel. We break the current and immediately the pointer starts downward, but

when the recalescence point is reached, the pointer gives a violent upward swing, after which it proceeds downward toward its initial zero point.

Finally, it may be calibrated and used as a hot-wire ammeter, an experiment and use which are quite obvious.

EXPERIMENT VI—LABORATORY THERMOPILE.

Heat and electricity are two different forms of energy. In the preceding experiment we had a striking demonstration of conversion of electricity into heat, but the converse transformation of heat into electricity is less readily demonstrated, particularly if a striking demonstration is desired. I have brought with me a few pieces of apparatus for measurements and demonstrations in thermoelectricity.

The first of these is a thermopile which I show you only as an example of simple design for such an apparatus for use in the student laboratory. Two sets of junctions are provided, one of which may be kept at the temperature of tap water or melting ice. The other set is immersed in a second beaker of water which may be heated to different temperatures. The thermopile is connected to some suitable galvanometer. By taking corresponding readings of the thermometer in the beaker which is being heated, and the galvanometer deflections, a calibration of the galvanometer as a thermoelectric thermometer is obtained.

EXPERIMENT VII—THERMOELECTRIC NEEDLE.

The current from a thermopile of the kind just described is relatively small for two reasons. The first of these is that the electromotive force corresponding to a temperature difference of one degree between the two sets of junctions is of the order of only 50 microvolts per junction, and the circuit resistance sets a limit to the current which flows as a result of this very small e. m. f. It is obvious therefore that if we wish to increase the current, we cannot do so by increasing the electromotive force, since this is entirely a function of the kinds of metals used, and we are already employing metals having a large thermoelectromotive force between them. The only practicable way therefore of increasing the current is to reduce the resistance of the circuit. When the

resistance is decreased sufficiently, a current of appreciable magnitude may flow.

The apparatus consists of an ordinary magnetic needle surrounded by a rectangular loop of copper strip. The ends of this loop are joined by a short piece of copper-nickel alloy with silver soldered junctions. The loop can be turned on the support for the magnetic needle so that both can be brought into the same plane. We allow the needle to assume its position in the magnetic meridian and then adjust the loop so that both are parallel. You will notice that even slight heating of one junction by touching it with the fingers is sufficient to deflect the needle. Heating the junction with a small flame produces a current sufficient to deflect the needle through a large angle.

With the apparatus there is included a second similar loop, but open at the ends and provided with binding posts. We can substitute this second loop for the first and send a direct current through it, of magnitude sufficient to deflect the needle through the same amount as in the first instance. An ammeter in the circuit shows the magnitude of this current which is therefore a rough measure of the thermoelectric current which flowed in the closed loop. We find that moderate heating of one junction causes a current of somewhere between 4 and 6 amperes to flow.

EXPERIMENT VIII—THERMOELECTRIC MAGNET.

In case we consider a current of 4 amperes beneath notice as a thermoelectric current, we can carry the process of reducing the resistance in the thermocouple circuit still further, and we are limited in this process only by considerations of the sort of apparatus we wish to construct. Some of you have already seen the experiment I now wish to show you, but to me it has always been so astonishing that I have never tired of seeing it, and I hope you will bear with me if it is not altogether new to you. The form in which I present it is perhaps different from any previous presentation you may have seen. At least, I shall justify my showing it on this ground.

This apparatus which we have called a thermoelectric-magnet is an electromagnet of reasonably good design,

with a special one-turn "coil" combined with a thermocouple. The material is a soft iron of very low carbon content, and it has been heated to redness and cooled extremely slowly so that it is very soft and its permeability is high. Its annular poles have been carefully ground to a plane surface as has also the surface of the armature which is to be held by the magnet.

To prove to you that it is a reasonably good electromagnet, I shall place in the recess of the magnet body a coil of 100 turns. I shall now ask two of the gentlemen in the front row to endeavor to pull the magnet and armature apart when I close the circuit through the coil with a small flashlight battery as the source. I might have asked eight gentlemen with four on each side, and the results would have been the same. My purpose in asking only two was to introduce an ample factor of safety, and avoid injury to the dignity of anyone in case the armature and magnet should have parted company. You will notice further that after the flashlight cell is disconnected, it still requires a very decided pull to remove the armature from the magnet. This is due to the fact that the grinding of the surfaces has been well done so that the air gap is exceedingly small. The molecular arrangement which results from the magnetizing force therefore remains after the circuit is broken, and it requires a very appreciable force to separate the two.

The one-turn coil is constructed of a copper bar of about 1 square centimeter cross section, and its ends are hard soldered to a bar of an alloy of 60 per cent copper and 40 per cent nickel. In addition the ends are provided with suitable means for heating the one junction and cooling the other. This magnetizing circuit constitutes one of the most striking demonstrations of Ohm's law. With the maximum attainable temperature difference between the junctions an electromotive force of about 1/50 volt is produced. The resistance of the copper bar is so exceedingly low, however, that a current of about 25 amperes flows for each millivolt of potential difference—a total slightly above 200 amperes.

The particular theremocouple which I am using is special in that it has an arrangement for using running

tap water for cooling the one junction and a copper plate in the form of a flame shield which assists in heating the other junction to a relatively high temperature. Although we have only a single turn in the magnetizing coil, the 200 ampere-turns produces an even greater magnetizing force than did the 100 turn coil with the flashlight battery which we used before. Conservatively, it may be said that the thermoelectric magnet with this special thermocouple will exert a force of at least 600 pounds on its armature.

Experiment IX—Radiation Thermopile.

During the war an attempt was made to detect enemy patrols after dark by heat radiation. I am informed that apparatus for the purpose was fairly well developed but that it never came into actual use. Such apparatus consists essentially of a thermopile of suitable design and a galvanometer of desired sensitivity. Thermopiles for detecting radiation have been known for a long time. The older form of radiation thermopile, however, consisted of numerous bismuth and antimony rods soldered together and arranged checker-board fashion in a surface on which radiation is permitted to fall. The thermal capacity of such an arrangement is great, and its response is consequently sluggish.

We began in our laboratory about a year ago to develop a sensitive radiation thermopile which would respond very rapidly to radiation intercepted by its heated junctions. This involved working out some interesting design principles on the basis of the requirements that can easily be established. The number of junctions may be made large, but the addition of junctions involves also the addition of resistance in the circuit. Beyond a certain point it does little good to add junctions. The hot junctions should be capable of collecting a large part of the heat which falls upon or near them, and the heat should not be conducted away rapidly from the hot junctions.

We finally worked out a method of constructing a thermopile of very fine metal ribbons, the junctions in which are electrically welded and arranged along a straight line. We then worked out the design of a parabolic re-

flector of cylindrical section, such that radiant heat is concentrated by the reflector along its straight line focus in which the hot junctions are located.

(Demonstration consisting of connection of thermopile to Type P galvanometer and showing deflection of galvanometer when the instrument is pointed towards people in the audience, an electric light, a lighted match or candle, and finally towards an electric heater placed as far away as the dimensions of the room will permit.)

EXPERIMENT X—PIEZOELECTRIC CRYSTALS OF ROCHELLE SALT.

The past few years have seen great development in the art of controlling to a constant value the high frequency of oscillation used in radio broadcasting. This is done with the aid of quartz crystals suitably cut and ground, which have the property of undergoing small changes in dimension when electric charges are applied to their surfaces. They also have the converse property of producing electric charges when they are put under mechanical stress. The piezoelectric property of a quartz crystal is relatively small. You may remember that the first application of piezoelectricity from a quartz crystal was made by Pierre Curie and his wife, Madame Curie, in connection with the use of an electrometer. With such a crystal they produced a compensating charge which just neutralized the leak from the electrometer produced by radioactive substances.

The demonstration of piezoelectricity which I am about to make depends on the piezoelectric properties of Rochelle salt in which this property exists to much greater degree than in quartz. The half crystal of Rochelle salt which I shall pass around for your examination is an artificially grown crystal. The process of producing crystals of this size is still a secret one, but I may say that it is carried on under conditions of extremely precise temperature control. It was developed by the late Charles F. Bush, Jr., and his associates in Cleveland.

We have developed a small unit for showing the very considerable charges developed when sections of such a crystal are subjected to mechanical shock. The device consists of such crystal sections suitably mounted, to which is connected a small neon lamp. Such a lamp requires about 130 volts for its excitation, and you will no-

tice that when I strike the end of the mounted crystals, the lamp flashes very perceptibly. The instantaneous voltage developed by this device is probably of the order of several thousand volts, which value is, of course, much reduced when the neon lamp is connected to it. Incidentally, it is a unit similar to this which is to be used in connection with the impulse counter previously shown you for measuring the rate of heart beat of a wren.

EXPERIMENT XI—ZELENY ELECTROSCOPE.

Experiments in ionization of air have in the past proved somewhat difficult to show to an audience because the ordinary gold leaf electroscope offered no simple means for measuring the effects of ionizing agencies. In the laboratory the rate of leak from an electroscope due to ionization can more easily be measured by observing the rate of fall of the leaf in a microscope provided with a divided eyepiece.

The Zeleny Electroscope, although it was devised by Professor John Zeleny in 1910, when it was my privilege to work with him at the University of Minnesota, has not hitherto become a well-known instrument simply because it lacked someone to point out to potential users its very excellent features. In this instance again the question of design and construction has proved an important one, because it was necessary to work out manufacturing methods that would keep the price where it represented excellent value. We spent about eight months of intensive development work on the instrument, and it is a source of genuine pleasure to be able to show you the results of that work.

The Zeleny Electroscope is an extremely versatile instrument. The outstanding feature is the manner in which the gold leaf operates. Instead of measuring the deflection of the leaf, we turn the leaf through 90° and let it strike the charged plate so that it, together with the insulated system to which it is attached, becomes charged to the potential of the plate. It is then repelled by the plate. If this charge is caused to disappear from the leaf system by ionizing the air around the top plate, the leaf loses its charge, and when its potential has fallen to a certain definite value, the leaf again strikes the plate and

the cycle goes on continuously so long as the ionizing agency is present. The stronger the ionization, the more frequently will the leaf strike the charging plate. Consequently, the intensity of ionization is directly measured by the frequency of oscillation of the leaf.

The instrument has been designed for use with a variety of ionizing agencies. These may be X-rays, alpha, beta and gamma rays from radioactive materials, photoelectrons produced by ultra violet light, ions from flames, or thermions produced by a wire heated to redness.

I have arranged the instrument for shadow projection so that an entire audience can easily see the oscillations of the leaf as ionizing agencies are presented to the instrument.

(There were shown the ionizing effects of alpha and beta rays, and the Hallwachs (photoelectric) effect; and the ionization caused by the emission of electrons from a heated wire and a flame. An attachment was shown simulating the three electrodes of a radio vacuum tube, with which data for a curve resembling the characteristic curve of such a tube could be obtained. Reference was made to the use of the Zeleny electroscope for measuring very high resistances.)

Experiment VII—Radio Demonstration Apparatus

The elusive radio wave is one of the rather difficult physical concepts for a student to grasp. During the period of development of radio to its present popularity, not to say its development into a household necessity, we have been conscious of the need for demonstration equipment with which the fundamentals of radio transmission and reception could be made real to the student. It is quite true, of course, that the average high school boy can speak glibly of frequency in kilocycles, wave lengths, inductance, capacity, etc., and in most cases he uses the terms correctly. Nevertheless, I think we can agree that the ordinary radio receiving set is not particularly well suited to the demonstration of the fundamentals of radio.

In thinking this problem through, we arrived at the conclusion, a few years ago, that the contact of an educational apparatus house, such as ours, with the field of radio must consist in being able to supply a demonstration apparatus which would fit into the regular demonstration equipment. We felt that it should be an apparatus that would actually demonstrate transmission and reception of the continuous electromagnetic wave. Hav-

ing arrived at this conclusion, we decided that we should produce a small vacuum tube outfit capable of generating oscillations, and design attachments suitable for radiating the waves produced. In addition there should be supplied apparatus with which the radiated wave could be detected, and apparatus which would tie up with the experience of the student in tuning the ordinary radio set. Whether or not we have been successful in accomplishing what we set out to do, I shall leave to your judgment.

The apparatus which I am showing you was designed to employ standard radio tubes which are good oscillators and which should preferably produce waves so short that experiments can be performed with them within the confines of the ordinary classroom or lecture room. A single transformer is used for supplying both the filament current and the plate potential. The circuit arrangement is of the push-pull type and half of the A. C. wave is applied alternately to the two tubes. The power supply transformer is designed for connection to the 110 volt, 60 cycle circuit.

Demonstrations.

(1) Oscillator only with large neon bulb to show that the tube is oscillating; also small neon bulb for use as a detector.

(2) Wave meter fitted with neon detector bulb and flashlight bulb detectors to measure wave lengths produced by the oscillator.

(3) Horizontal antennae attached to oscillator to demonstrate radiation of the electromagnetic wave. Use of linear receiving oscillator with flashlight bulb and thermogalvanometer, and also the linear oscillator with the series of flashlight bulbs to show distribution of current.

(4) Use of vertical antenna with coupling loop to show transfer of power from the oscillator to the antenna and effect of variation in coupling.

(5) Use of horizontal and vertical antennae simultaeously and the combination of two trains of polarized waves.

(6) Experiment with Lecher wires to show measurement of wave length by determining the nodes in standing waves on the parallel wire system. Use of exploring lamp for locating nodes and loops in this system.

I wish to repeat my expression of appreciation for the opportunity of giving you this demonstration of apparatus, which, I trust, has been as interesting to you as it is to me. If you have questions or if you would like to see some of these things at closer range, I shall be very happy to give you such further information or demonstration as you may wish.

After the morning session the members of the Association and guests were entertained at lunch by the Institute. After lunch a vote of thanks was given to the Institute and to Prof. Drisko who had charge of the arrangements.

THE CYCLICAL NATURE OF THE UNIVERSE.

By Prof. Norman E. Gilbert,

Dartmouth College, Hanover, New Hampshire.

No intelligent being can look about at the infinitely complex system of Nature in which he lives, and of which he is a part, without asking himself whence it came and whither it goes. We may look in the first two chapters of Genesis and find two unreconcilable accounts of the creation of the universe including this earth and its inhabitants. We may find similar poems in the sacred books of other religions and elsewhere. The question has been a living one since the dawn of history.

In recent years the geologists and their kin have given us a more detailed story of the development of our little earth but nowhere has any scientist, as such, broached any hypothesis regarding the creation of the matter and the energy which make up our universe. The Biblical account, and all the others, start us off as a full-fledged going concern. Science has examined the processes of operation and has arrived at three fundamental conclusions known as the laws of Conservation of Matter, Conservation of Energy or the First Law of Thermodynamics, and the Second Law of Thermodynamics. The last states that our available supply of energy is running down and condemns the universe to ultimate stagnation when everything comes to a dead level of temperature, the "wärmetod" for which we have no adequate expression.

Science progressed rapidly during the last century and in the early nineties many believed that our knowledge of the fundamental processes of Nature, in so far, at least, as physics is cencerned, was practically complete. Maxwell had reduced electromagnetic phenomena and radiant energy to a common basis. Hertz, at Bonn, had confirmed Maxwell's work by a brilliant series of experiments and a few years later Nichols and Hull, at Dartmouth, rendered assurance doubly certain by confirming Maxwell's predictions concerning the pressure of light. A few questions remained unanswered but few doubted

that the answers would be discovered and that they would fall in with the established order.

It is an interesting fact that Hertz himself, in the very act of establishing beyond apparent question Maxwell's theories, discovered the photoelectric effect, one of the phenomena which have established the quantum theory which is still in apparently hopeless conflict with Maxwell. But about 1895 things began to happen. The discovery of X-rays, of radioactivity, of ionization, and the isolation of the electron followed one another in rapid succession and physics received a new lease of life. The twenty years preceding the war witnessed the accumulation of such a mass of undigested experimental facts as was never seen before. Theories were formed about which the facts could be grouped but these were incomplete and mutually contradictory. It finally became clearly recognized that only by more exact measurements of the phenomena involved was there any hope of bringing order out of the existing chaos. I am recalling to your memories today the stories of several such investigations, some interesting conclusions which may be drawn from them, and am following Professor Millikan in some far-reaching speculations.

My first story has to do with leaking electroscopes. The first electroscope dates back to Dr. Gilbert, friend and physician to Queen Elizabeth. The first gold-leaf electroscope, as we know it today, was used by Bennett in 1787. These electroscopes gradually lost their charges. New and better insulators were used but still the instruments leaked. The charges were found to be creeping over the surface of the insulator. These were kept polished and the whole kept dry under glass cases with dishes of deliquescent material but still they leaked. The air molecules were blamed. It was thought that they became charged as they bombarded the charged leaves and so carried away the charge. The discovery of the ionization of gases showed this to be at least a half truth. But the free ions in the air were quickly used up and no more charge could be carried away by this means until more were made. Flames, ultraviolet light, X-rays, radioactive substances, etc. were found to be active ionizing agents.

All were removed and still the electroscopes leaked. It was now possible to count the number of molecules of air which were ionized per second in the enclosure by observing the rate at which the charge leaked away. But what could cause this continuous ionization? Traces of radioactive matter in the case of the instrument or highly penetrating radiations of some sort seemed the only answer. McLennan and Burton, and Rutherford and Cooke, reduced the leak by 30% by enclosing the electroscope in thick-walled metal boxes intended to screen off stray radiations. The answer then was a highly penetrating radiation. Did it come from the earth below or from the air above? Göckel, a Swiss, Hess, an Austrian, and Kolhörster, a German, took their instruments up in balloons and found at first a decrease in leak and then an increase with altitude. Kolhörster reached an altitude of 9 k. m. After the earth radiation was screened off by the air there remained a highly penetrating radiation from above reaching the earth from "somewhere in space."

The electroscope was next lowered into deep crevasses in Alpine glaciers and so exposed, by the rotation of the earth, to the sun, to the moon, to the milky way, and to the comparatively empty regions of space. The radiations were found to come, not from the sun, moon, or stars but equally from all directions in space.

The exploration of these cosmic rays was taken up energetically by Millikan and his associates about 1925. Sounding balloons, with self-recording electroscopes, were sent up and records to heights of 11 kilometers and 15 kilometers were obtained. The latter balloon had penetrated 9/10 of the atmosphere. The results indicated that the rays possessed a much higher penetrating power than had been supposed. Electroscopes were lowered into snow-fed lakes in the High Sierras and in the Bolivian Andes and the results showed practically identical absorption curves. Millikan decided that the time had come for measurements of the utmost accuracy on these elusive radiations.

With Dr. Cameron he designed and constructed new electroscopes eight times as sensitive as those used before. They sought deep lakes in the high mountains. Ordinary

lakes fed by streams which contain radioactive materials leached from the soil were not suitable. The lakes must be fed by water from fresh snow only. Arrowhead Lake and Gem Lake in the High Sierras were chosen. These are 140 feet and 225 feet deep. Though their elevations differ by 4000 feet and their distance apart is 250 miles the curves connecting radiation intensity and depths, measured in equivalent meters of water from the top of the atmosphere, are identical. These curves were now analyzed, meter by meter, by means of tables prepared by Gold in 1909, and the absorption coefficient at each meter of depth was determined. Sudden changes in the values of this absorption coefficient indicate that beams of definite frequency have been absorbed. Three or possibly four such breaks were found indicating that the cosmic rays consist of three or four homogeneous beams of definite frequency. This was a great triumph for the painstaking accuracy of this work, but what does it mean? The absorption coefficients determined were far smaller than any before determined and indicated frequencies far beyond the known gamma rays and extrapolation is a dangerous proceeding.

We passed by without mention the remarkable piece of work done by Gold in preparing his tables of absorption coefficients and we shall pass by another story, that of the brilliant Englishman named Dirac, who has derived by means of the new Wave Mechanics a formula connecting absorption coefficients with vibration frequencies or wavelengths. His formula has been criticized and a mistake pointed out but the general validity of the fomula is not seriously questioned provided we grant the premises upon which it is founded. At any rate Dirac's formula gives values of vibration frequencies, corresponding to Millikan's three absorption coefficients, which are sufficiently interesting. These frequencies lie in the spectrum several octaves beyond the highest frequency gamma rays heretofore known.

We will leave Pasadena for a time, will cross the ocean, and take up another story. Nearly seventy years ago Mendeleef arranged the known elements in the order of their atomic weights (there were two or three trans-

positions) and found that they fell into positions in a table which correspond remarkably with their chemical and physical properties. It was also noted that many of the atomic weights, based upon the weight of hydrogen as unity, were very nearly whole numbers. With more careful determination of the atomic weights these deviations from whole numbers, far from disappearing, became firmly established and, in many cases, the atomic weight as determined lay about 0.8 of 1% below the whole number. Was something wrong with the atomic weight of hydrogen? If 1/16 the atomic weight of oxygen were taken as the unit many atomic weights were practically whole numbers but this made the atomic weight of hydrogen 1.008. Is the nucleus of the hydrogen atom, called the proton, the building stone of the heavier atoms and does some mass disappear when the atoms are built? Again it became evident that only a determination of atomic weights, far more exactly than any before attempted, could answer these questions.

Sir J. J. Thomson suggested a method and discovered the first isotopes. Dr. Aston has improved the method and, in the course of ten years, has perfected a set of apparatus and developed a technique by which, in some cases in a few hours time, he can determine an atomic weight to an accuracy of two significant figures beyond the value previously accepted. This apparatus is his "positive ray spectrograph" and it has won for him the Nobel prize.

Aston uses the well known method of measuring the ratio of the charge to the mass of an ion. An electric heater is placed in a recess of an ionization chamber, consisting of a glass bulb, and a salt of the element to be examined is placed in the heater. The bulb is sealed to the spectrograph and the whole is exhausted. Some of the salt is vaporized and the ions fill the chamber. The entrance to the spectrograph is a narrow slit between two pieces of metal. This metal is negatively electrified and a narrow stream of positively charged ions are projected through the slit. There may be several kinds of ions in the stream all carrying the same elementary charge, or a simple multiple of this charge, but differing from one

another in mass. Let us limit our attention to those ions having one particular value of e/m. Even these will possess different velocities as they emerge from the slit in the cathode. The beam is first subjected to an electric field. By this it is dispersed or spread out into a spectrum of velocities. This dispersed beam next passes through a magnetic field, whose dispersive power is half that of the electric field, so directed as to recombine the dispersed beam and to bring all the ions having one value of e/m to a focus in a narrow line on a photographic plate. All the ions having another value of e/m are brought to a focus in a neighboring line on the plate. When developed the plate has the appearance of an ordinary spectrogram, each line corresponding to a particular value of e/m. Since all values of e are the same the positions of the lines give the relative values of the masses of the ions and these can be compared directly with an oxygen line.

The first results were the discovery of many isotopes, i. e. atoms having the same chemical properties but different atomic weights. For example chlorine was found to have two atoms, whose weights are 35 and 37. The 35 line was about three times as dense as the 37 line indicating that the 35 atoms are three times as numerous as are those of weight 37. A mixture in this proportion would make the atomic weight of chlorine 35.5 which is the value determined by other methods. Tin is found to have as many as eleven isotopes.

The next important development was that practically none of the atomic weights including those of the isotopes, are exact whole numbers. But now, by dividing the atomic weight by the number of protons in the nucleus, Aston was able to find the mass of the protons as they appear in the different elements. When plotted in the order of the atomic numbers these masses fall on a smooth curve. Taking a line through oxygen as unity the hydrogen proton lies well above this line at 1.0077. The curve slopes downward, crosses the unity line at oxygen, for a time lies below this line, then slopes upward to uranium which lies a little above the line.

We will digress for a moment for another story which must be briefly told. Shortly after the value of e/m for

the electron was measured theoretical considerations led to the belief that the mass of the electron varied with its velocity, approaching infinity as the velocity approached that of light. This was partially verified by experimental test but the increase in mass is only one half of one per cent at a velocity of 100,000 miles per second and velocities above this were not easy to obtain. Other considerations led Einstein to the formulation of his special theory of relatively and a direct result of this theory is that mass may be transformed into energy. Einstein computed that the amount of energy corresponding to one gram of matter is $9x10^{20}$ ergs. At this rate a gram of dirt from the garden would heat my house for 125 years and save me the price of 20 tons of coal per season.

Returning to Aston's curve consider the heavy elements, many of which are radioactive with the discharge of a helium ion from the nucleus. When the helium ion is ejected its mass immediately changes to that indicated on the curve while the remaining protons, 234 in the case of uranium, slide down the curve to the position of the next element, each losing some mass. So long as the total change is a decrease in mass energy will be evolved and this will appear as kinetic energy of the ejected particle. Only those elements can be radioactive, at least with the ejection of a helium nucleus, for which this ejection is accompanied by a decrease in mass. Among the lighter elements such an ejection would mean an increase of mass and radioactivity among these is impossible. To disrupt these nuclei requires the expenditure of enough energy to supply the mass acquired. I regret that time will not allow us to take up the story of Sir J. J. Thomson's experiments in which he uses high speed alpha particles to chip protons off the nuclei of these elements. The energy of the alpha particle used must be at least equal to the amount required to supply the additional mass evolved as computed from Aston's curve.

We must digress again to consider for a moment Planck's contribution to our list of stories of great results coming from the most exact measurements. Something was wrong with the classical theory of radiation. A black body did not radiate as it should. Planck was driven

to the almost ridiculous conclusion that radiant energy is given off, and absorb, in chunks, or "quanta" and that the amount of energy in each quantum is proportional to the vibration frequency of the radiation. He determined the value of the constant of proportionality which is called Planck's constant. Since then the same necessity for quanta and the same constant of proportiality have turned up in photoelectric phenomena and in many other places. The quantum theory is essential to the explanation of many phenomena and Planck's constant is one of the fundamental constants of nature.

Let us now return to Pasadena and Professor Millikan. From Aston's curve he computed the amount of mass which would disappear if sixteen protons were compressed together to make an atom of oxygen, one of our most common elements. Next, from Einstein's equation, he computed the amount of energy this mass would represent. Next, from Planck's equation, he computed the frequency of a quantum of radiant energy containing this amount of energy. From Gold's table he found the absorption coefficient in water and—it agreed with one of the coefficients he had already determined for his cosmic ray absorption curve. He had discovered the birth cries of Oxygen. Further computations showed that the other two absorption coefficients corresponded to the birth of Helium and of Silicon.

It has long been a favorite amusement to speculate upon the conditions under which the elements might be formed. Since no one could contradict, the interior of the stars seemed a likely laboratory. But all agree that the cosmic rays come equally from all directions in space. Even if elements were formed in the interior of the sun these rays, announcing the event, could never get out. They would be absorbed in the first few meters and ultimately be radiated as heat. Jeans thinks it far more likely that in the interior of the sun and other stars protons and electrons may actually be pressed together and matter be thus transformed into heat. Astro-physicists have long sought a possible source of the enormous amounts of heat radiated by the sun. All other sources have proved inadequate. This might be sufficient. If this is correct

then the sun is slowly radiating away its very substance and must ultimately disappear as a source of heat.

On the other hand it appears that there is an inexhaustible supply of protons and electrons distributed through empty space and that the conditions there are right for their condensation into atoms. These may collect and condense into new stars and the course be run again.

One step in the cycle is missing. Does the radiant energy condense into protons and electrons? There is no evidence whatsoever that it does and yet such condensation seems to be necessary to complete the cycle. Without this the supply of atom-building material must ultimately be exhausted and the universe must radiate itself away. Such condensation would seem to be contrary to the second law of thermodynamics but many authorities believe that this difficulty is not unsurmountable.

We are indulging in the wildest speculations but there is something so attractive in the thought that the universe may be continually renewing its youth that we may perhaps be pardoned for allowing our thoughts to leap the boundaries of demonstrated fact and soar for a moment into the realms of fancy.

EXPERIMENTS IN PHYSICS HEAT.

By Prof. Gordon B. Wilkes,
Massachusetts Institute of Technology.

1. A thermo-pile was used to produce enough electrical energy to light a lamp, to operate a bell, a spark plug, and a small fan, all of which were conveniently mounted on a board.

2. The current from a thermo-couple with one leg in ice water and the other heated with a Bunsen burner, passing through a large copper wire, produced magnetic effect enough to lift a five kilogram weight.

3. A piece of No. 18 iron wire about 8 feet long is mounted vertically with a pointer fixed near the bottom to magnify its expansion. It is heated by passing a 20 ampere current through it, and then upon cooling, shows very clearly the recalescence point.

4. Trevellian's rocker. A heated copper bar with groove surface, is laid on a lead block. The expansion of the lead combined with low thermal conductivity causes the copper bar to rock rapidly back and forth, as it makes contact first on one ridge and then on the other, producing a humming sound.

5. Two bricks are shown, upon which the flame from a horizontally mounted Bunsen burner has been directed for an hour or so. One is of relatively non-conducting diatomaceous earth and

the other is of carborundum. The first is red hot on the face, and the second is black. The back of the non-conducting brick is only warm to the touch, and may be handled without discomfort, while the back of the carborundum brick is so hot that it immediately changes water thrown against it into steam. This type of insulating brick is convenient to use because it may be cut or bored with a dull knife.

6. A long coil of resistance wire, heated with a 20 ampere current, is covered with 85 per cent magnesia near its middle. Within the cover it becomes red hot, while the ends are still black. A small wire with a glass tube slipped over the middle of it, shows just the reverse, dark under the tube, and red at the ends. This is due to the fact that the glass tube, being of small diameter, radiates rather than conserves the heat. There is a critical radius, for each material, and a cover, in order to be efficient, must have a radius more than the critical radius. For concrete the critical radius is 4 inches and for 85 per cent magnesia, ¼ inch. For instance, the pipes on the arena skating floor are covered with concrete, of less than the critical radius, so the concrete actually facilitates the freezing.

7. A small brass cylinder 1⅜ inches in diameter and 4 inches long, closed at the lower end, with a small opening just above the bottom, is packed with cracked ice. It is put in an hydraulic press and a close fitting piston is forced into it with a pressure of 10,000 pounds. The increased pressure causes the ice to melt and the resulting water is forced out through the small hole, and being below its freezing temperature at normal pressure, immediately freezes, producing a pencil of ice projecting 6 or 8 inches from the cylinder.

8. A large flask full of boiling water is tightly corked and inverted. Upon cooling, vigorous boiling commences, and continues for some time.

9. Water is placed in a Dewar flask, and the flask connected to a drying tower containing sulphuric acid, and a vacuum pump. The air is exhausted, and at the low pressure, the water boils vigorously, absorbing heat enough to produce ice crystals in itself.

10. The same principle is illustrated by the cryophorus. When one bulb is immersed in a freezing mixture of ice and hydrochloric acid, ice forms in the other bulb.

11. The critical temperature of carbon dioxide, 31 degrees centigrade is illustrated as follows: A tube containing liquid carbon dioxide is projected on the screen showing the meniscus very clearly. Upon warming a little, the carbon dioxide vaporizes, and the meniscus disappears. If the tube is now cooled, the liquid reappears.

13. Liquid carbon dioxide is allowed to flow from a tank into a canvas bag. The sudden change of state absorbs heat from some of the carbon dioxide and converts it into a solid. This solid carbon dioxide is of a snow-like appearance, and after being compressed, is finding extensive use as the so called dry ice.

14. An Icy Ball refrigerating unit was shown. This is made by the Crosley Radio Company, and is of such simple construction that it can be used advantageously in teaching the principles of commercial refrigeration. It operates by heating an ammonia solution in one end, thus driving the anhydrous ammonia out of solution and condensing it in the other end. The unit is then placed in a chest, and the liquid NH_3 is slowly reabsorbed in the water. The cooling effect is caused by the latent heat of vaporization of the NH_3 and is effective for 24 hours or more.

DEMONSTRATION OF COLOR APPARATUS.

By W. R. Brown,
Classical High School, Providence, R. I.

This apparatus to demonstrate the principles of absorption and reflection of color is used in the Classical High School of Providence. Red, green, blue and white natural glass mazda lamps were concealed in a box, from the rear of which colored pictures were shown which changed their characteristics in a striking manner when illuminated by the various colors. A plaster cast when illuminated from various angles seemed to change its facial expressions completely, and illustrated the good or detrimental effects of flood lights and their shadows upon statues. A constant speed motor apparently slowed down when contrasted in dim and brilliant illumination, and illustrated why an automobile, although at the same speed, apparently travels faster at night than in daylight. The glare of headlights was also illustrated.

PROBLEM DEPARTMENT.

Conducted by C. N. Mills,
Illinois State Normal University.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problems, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

LATE SOLUTIONS.

1097, 1098, 1099, 1100, 1101, 1102. *Everett Pitcher, Cleveland, Ohio.*
1107, 1108. *W. E. Buker, Leetsdale, Pa.*
1107, 1108. *G. J. Cain, Raymond, Miss.*

SOLUTIONS OF PROBLEMS.

1109. *Proposer unknown.*

Are there any flaws in this proof: (See proof on p. 212, Feb., 1930)?

Solved by Louis R. Chase, Newport, R. I.

First, there is no proof that any two altitudes will intersect, but this is trivial and will be taken care of incidentally.

Excluding the obvious case of the right triangle, to render the proof unassailable it will be necessary and sufficient to show that S and O must both fall *on the same side* of D. This may be accomplished by proving the following lemmas:

(1) In any acute triangle, the altitudes fall within the triangle.
(2) In any obtuse triangle, the altitude from the vertex of the obtuse angle falls within the triangle; the others, without.
(3) In any obtuse triangle, the altitudes from the vertices of the acute angles meet the third altitude produced beyond the vertex of the obtuse angle.

For proving (3), Euclid's Parallel Postulate would be useful, although in our modern text-books this itself would require demonstration. "That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles." (Heath)

Note by George Sergent, Tampico, Mexico.

This proof is O. K.

1110. *Proposed by H. D. Grossman, Brooklyn, N. Y.*

What proportion of all rational fractions are in their lowest terms?

Note by Louis R. Chase, Newport, R. I.

W. W. Rouse Ball in his Mathematical Recreations and Essays states that it is known that if two numbers are written down at random, the probability that they will be mutually prime is $6/\pi^2$, giving the following reference: "Note on π by R. Chartres, Philosophical Magazine, London, series 6, vol. XXXIX, March, 1904, p. 315."

1111. *Proposed by L. M. Hollingsworth, San Diego, Calif.*

Nine marbles one inch in diameter are placed in a layer at the bottom of a box 3 in. square. Four more marbles are placed above these, and a fifth marble at the top, all of the same diameter, and placed to form a pyramid of least height. How many points of contact among the marbles? What is the height of the pyramid?

Solved by Louis R. Chase, Newport, R. I.

Let n be the number of layers, c the number of contacts, of any such pile. Counting the contacts for $n=1, 2, 3, 4, 5$, we find c to be 0, 8, 36, 96, 200, respectively, in which each of the third differences is 12. By induction we can show that by extending the count the third differences will continue to be constant.

Therefore $c=pn^3+qn^2+rn+s$, which by substitution resolves into $c=2n^3-2n^2=2n^2\ (n-1)$. For $n=3$, $c=36$.

Let d be the diameter of each marble. In a square pile of 5 marbles the lines of centers form a square pyramid each of whose edges is equal to d. The altitude of this square pyramid is $\frac{1}{2}d\sqrt{2}$. The height of a pile of n layers becomes $h=d+\frac{1}{2}\sqrt{2}\ (n-1)d$.

For $n=3$, and $d=1$ in., $h=2.4142\ .\ .\ .\ .$ in.

Also solved by *Raymond Huck, Johnston City, Ill.* One incorrect solution received.

1112. *Proposed by Norman Anning, University of Michigan.*

In a design of a double turnout from a straight track the engineer comes upon the following formula (See Webb, Railroad Construction, page 306): 2 vers$A$ = vers $2B$. Prove $\cot^2A(1+2\cot^2B) = \cot^4B$.

Solved by Milton Jenkins, Hampton, N. J.

$$\begin{aligned}
2\text{ vers } A &= \text{vers } 2B\\
2\,(1-\cos A) &= 1-\cos 2B\\
2-2\cos A &= 1-2\cos^2 B+1\\
\cos A &= \cos^2B=1-\sin^2B\\
\csc^2B &= \sec A\csc^2B-\sec A\\
&\text{(Dividing by }\cos A\sin^2B)\\
\csc^2B &= \sec A\,(\csc^2 B-1)\\
1+\cot^2 B &= \sec A\cot^2 B\\
1+2\cot^2 B+\cot^4 B &= \sec^2 A\cot^4 B\\
1+2\cot^2 B &= \cot^4 B\,(\sec^2 A-1)\\
1+2\cot^2 B &= \cot^4 B\tan^2 A\\
\cot^2 A+2\cot^2A\cot^2 B &= \cot^4 B\\
&\text{(Dividing by }\tan^2 A)\\
\cot^2 A\,(1+2\cot^2 B) &= \cot^4 B
\end{aligned}$$

Also solved by *A. J. Patterson, Wheeling, W. Va.; Mildred Hopkins, Montezuma, N. Mex.; Raymond Huck, Johnston City, Ill.; Louis R. Chase, Newport, R. I.; Sudler Bamberger, Harrisburg, Pa.*

1113. *Proposed by I. N. Warner, Platteville, Wis.*

Disprove the old theorem found in earlier geometries.

The number of edges of any convex polyhedron is 2 fewer than the sum of the number of its faces plus the number of its vertices, or $E+2=F+V$.

Note by George Sergent, Tampico, Mexico.

Geometers credit the proof of this famous theorem to Euler. In the February number of the "Mathematics Teacher" David Eugene Smith is quoted as saying that the theorem has no exceptions. Whoever disproves this theorem will deserve fame.

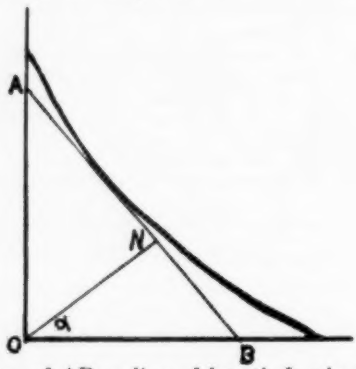
1114. *Proposed by Clyde Bridger, Walla Walla, Wash.*

A ladder of length L stands upright beside a wall of a building. The

wall of the building and the surrounding ground are considered as being at right angles to each other. (a) To what curve is the ladder tangent as it slides down the wall and along the ground (in a plane $\perp$ to line of intersection).

(b) What is the locus generated by any point (except the two end points) on the ladder if it falls as in (a). Give its equation.

Solved by Irene Price, Oshkosh, Wis.



(a). The equation of AB, a line of length L whose end-points lie on the coordinate axes, is

$$F(m) = x \cos m + y \sin m - L \sin m \cos m = 0, \quad (1)$$

where m is the angle between the X-axis and the normal to AB.

(m in the figure is shown as "alpha")

It is required to find the envelope of the line AB when it moves such that the X-intercept varies from 0 to L.

Taking the first derivative;

$$F(m) = -x \sin m + y \cos m + L \sin^2 m - L \cos^2 m = 0. \quad (2)$$

The equation of the envelope is obtained by eliminating m from the equations (1) and (2). We get

$$x = L \sin^3 m \text{ and } y = L \cos^3 m.$$

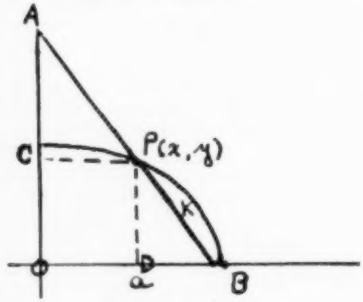
Hence, we have the parametric equations for the hypocycloid.

(b). To find the locus generated by any point on AB when it moves as described in (a), let the point P be at a distance k from the X-intercept. Draw CP and PD parallel to the coordinate axes. Then in triangles ACP, PDB, and ABO, we have

$$a/L = (a-x)/k. \quad (a = OB) \quad (1)$$

$$\text{and } (a-x)^2 + y^2 = k^2. \quad (2).$$

Eliminating a from (1) and (2), we get



$$\frac{x^2}{(L-k)^2} + \frac{y^2}{k^2} = 1,$$

which is the equation of an ellipse.

Also solved by *Louis R. Chase, Newport, R. I.; W. E. Buker, Leetsdale, Pa.; Sudler Bamberger, Harrisburg, Pa.; Paul Lewis, Tahlequah, Okla.; A. J. Patterson, Wheeling, W. Va.;* and by *George Sergent, Tampico, Mexico.*

PROBLEMS FOR SOLUTION.

1021. *Proposed by W. E. Buker, Leetsdale, Pa.*
Find the positive root of
$X+X^{1/2}+X^{1/3}+X^{1/4}=5.$

1022. *Proposed by Louis R. Chase, Newport, R. I.*
Given the line of base, mid-point of base, vertex, and vertex angle, to construct the triangle. A geometrical solution is desired.

1023. *Proposed by J. K. Thornton, Fillmore, Calif.*
How many acres in a square field that takes as many board feet of fence 4 feet high, as the field has area in square feet?

1024. *Proposed by H. D. Grossman, Brooklyn, N. Y.*
Consider two congruent triangles that can be brought into coincidence only by a rotation of one of them through a third dimension. How, by cutting the triangles, could we effect this coincidence by motion in a plane only?

1025. *Proposed by F. P. Hennessey, Astoria, L. I., N. Y.*
(*Taken from a recent examination.*) There are three numbers such that (1) the sum of the squares of the first and second, added to the first and second equals 32; (2) the sum of the squares of the first and third equals 42; (3) the sum of the squares of the second and third, added to the second and third equals 50. Find the numbers.

1026. *Proposed by I. N. Warner, Platteville, Wis.*
A railway embankment across a valley has the following dimensions: width on top, 20 ft.; width on base, 45 ft.; height, 11 ft.; length of top, 1020 yd.; length at base, 960 yd. Find the volume in cubic yards. Solve by prismatoid formula and check by cutting into other known solids.

SCIENCE QUESTIONS

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

1. *What is interesting to your students?*
2. *What do you like to teach them?*
3. *Do they like it?*
4. *Are teaching and selling alike? If not, why?*
5. *Do pupils like subjects that make them think?*

Please send your final examination papers especially "completion" tests, "right or wrong" questions, "underline the right statement," etc., etc.

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552. Highriter's Tests in Physics (Concluded). Each question counts 5 points.

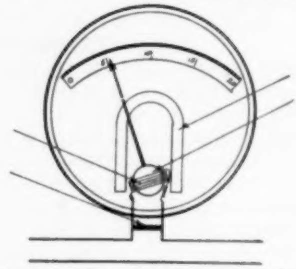
PHYSICS EXAMINATION—ELECTRICITY

Electrical Units, Electrical Measurements, and Heating Effect of Electricity.

1. Write the name of the unit of electrical (A) current, (B) power (C) energy (D) pressure (E) resistance
(A)..(B) ....
(C)................................ (D)................................ (E) ....
2. Ohms law states that the current in a circuit is ....
proportional to the resistance of that circuit, and................................
proportional to the ....
Another way of stating Ohms law is: The intensity of current in any circuit is equal to the electromotive force................................
by the..of the circuit.

3. The three effects which electric currents produce are ...., ... and .... Currents are usually measured by their ....effect.

4. In the diagram, add the proper prefix to the word meter, and label each of the four arrows.



....................................METER

5. A voltmeter is a ....resistance galvanometer, and is always connected in ....
An ammeter is a ....resistance galvanometer, and must always be connected in ....

6. Underline the correct expression, and fill in the blanks. In order to make a voltmeter read higher voltages, a (A) larger (B) smaller resistance must be connected in ....with the meter.
In order to make an ammeter read a higher current, a shunt of (A) larger (B) smaller resistance must be connected in .... with the meter.

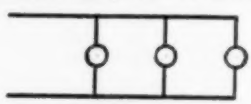
7. Show by a simple diagram an electric lamp connected to a line, with meters so connected as to read the current and voltage of the 1 lamp.

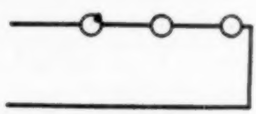
8. An electric flatiron, connected to a circuit whose pressure is 108 volts, lets 4.5 amps flow through the coil of the iron. The resistance of the iron is ....

9. The four factors upon which the resistance of a conductor depends are (1).................... (2) .... (3) ....(4)....................

10. Copper has a specific resistance of 10.4. The resistance of 600 ft. of copper wire, the diameter of which is 0.012 inches is ....

11. Each lamp has a resistance of 90 ohms.

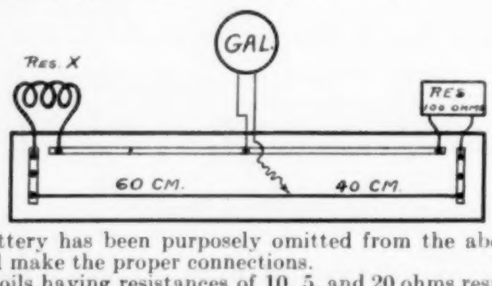




Combined resistance.................... Combined resistance ....

12. A generator, whose pressure is 115 volts delivers 50 amperes to a customer over a line whose resistance is 0.08 ohms. The customer receives a voltage of ....

13. The resistance of X is . ...



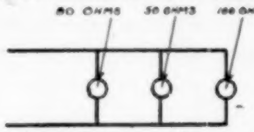
14. The battery has been purposely omitted from the above diagram. Add it and make the proper connections.

15. Three coils having resistances of 10, 5, and 20 ohms respectively, are connected in parallel. Their combined resistance is ....

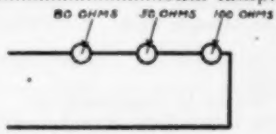
16. An electric iron takes 5 amps on a 110 volt circuit. Power costs

10 cents per kilowatt hour. The cost of operating the iron for six hours is ....

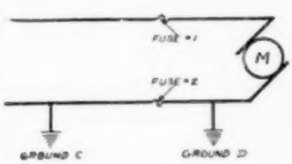
17. The brightest lamp is the .... ohm lamp.



The brightest lamp is the .... ohm lamp.



18. The efficiency of a small tungsten electric lamp is about one .... per ....



19. One side of a transmission line is usually grounded (Connected to the ground), as shown at "C" in the diagram. Suppose the motor "M" becomes accidentally grounded at "D" as shown. In case the motor now becomes slightly overloaded, which fuse (No. 1 or No. 2) will blow; or will both blow? Answer *No. 1*, *No. 2*, or *both*.

20. An electric heater has a resistance of ten ohms, and requires twelve amperes of current. In a half hour it will produce .... calories of heat.

UNIT TESTS IN GENERAL SCIENCE.

553. Here is another test from Miss Opal Burres, Head of the General Science Department of West Technical High School.

The General Science course consists of 10 units and a test is given at the close of each unit. After the unit "Water," the following test was given:

9B Science Test—Water

Teacher.............................. Name.............................. Grade...............

1. Water is composed of ....
2. A cubic foot of water weighs ....
3. Water pressure is exerted in .... direction.
4. Water which sinks into the ground forms .... by..............................
5. "Hard" water contains .... It may be "softened" by adding.............................. Hard water is *expensive* because..............................
6. Rain occurs when..............................
7. What causes rain?..............................
8. Why do you add salt to ice when freezing cream?..............................
9. Why are surface wells dangerous?..............................
10. How do cisterns and wells differ?..............................
11. Name 5 sources of water supplies for towns: (1).............................. (2) .... (3) .... (4) .... (5) ....
12. Indicate which of the above sources you consider safest, and explain why you think so.
13. How may over night campers provide safe drinking water?..............................
14. Name 4 industries requiring a great deal of water. (1).............................. (2).............................. (3) .... (4) ....
15. Name 5 uses for water in your home. (1).............................. (2).............................. (3).............................. (4).............................. (5)..............................
16. Why do you place ice at the top, and food below in an icebox? ....
17. Where do these cities obtain their water? (1) Denver.............................. (2) N. York City.............................. (3) Cleveland..............................
18. Where is the danger from impure water greatest, in a city, the country or a small town?.............................. Why?..............................
19. Why must cities keep a big *reserve* water supply?..............................
20. "An adequate water supply depends upon our forests." Explain this statement (on back of paper.)

HELP FOR HUBER.

WANTED—A True-False Test on Electricity.

554. E. L. Huber, Lima Public Schools says:

Dear Sir:

Here is a modified essay test, I have used to cover the units of "Heavenly Bodies and Electricity."

Since I am still a novice in the art of constructing tests I find your department a constant help.

I am wondering if you can publish, at some later date, a *true-false test covering electricity which would be suitable for Physics.*

General Science 9B.

Use the word or words which will make the sentence a complete statement.

The North Star is called ——(1).	1. ....
It is located from the Big Dipper by the ——(2) stars.	2. ....
Some day the Pole star will be ——(3).	3. ....
The rising and setting of heavenly bodies is due to the earth's ——(4).	4. ....
The yearly changes in the sky is caused by the ——(5) of the earth.	5. ....

The earth turns on its ——(6) every ——(7) hours causing ——(8) and ——(9).	6. ...... 7. ...... 8. ...... 9. ......
The time from new moon to new moon is ——(10). The phases of the moon are due to the fact that it shines by ——(11). A solar eclipse occurs when the ——(12) comes exactly between the ——(13) and ——(14).	10. ...... 11. ...... 12. ...... 13. ...... 14. ......
The inferior planets are ——(15) and ——(16).	15. ...... 16. ......
Lima is on the 82.5° meridian when we use eastern time we are ——(17) hour too ——(18). If we use central time we are ——(19) too ——(20).	17. ...... 18. ...... 19. ...... 20. ......
The seasons of the year are caused by the ——(21) of the earth's axis. In summer we are ——(22) the sun than in winter. We receive more heat in summer because the sun's rays ——(23) the earth ——(24) so that they cover a ——(25) area. Stars are ——(26) which shine by ——(27) light.	21. ...... 22. ...... 23. ...... 24. ...... 25. ...... 26. ...... 27. ......
The sun is farthest north in the sky at the ——(28). Fifteen degrees longitude corresponds to ——(29) time. Light travels with a speed of ——(30) per second. A star at the sky's north pole is always above our ——(31). Like poles of magnets ——(32) each other. The principal magnetic substances are ——(33) and ——(34). The earth is a ——(35), having a ——(36) pole near the Geographic North Pole. Bodies which can be charged by friction are ——(37) A positive charge is produced when ——(38) is rubbed with ——(39). A condenser consists of ——(40) separated by ——(41). The electrodes of a simple cell are ——(42) and ——(43). The positive electrode of a storage cell is ——(44). The negative electrode is ——(45). The storage cell is used to store ——(46). The object to be plated is hung from the ——(47) terminal of the battery. The ——(48) with which we are plating is hung from the ——(49) terminal. ——(50) current must be used in electroplating.	28. ...... 29. ...... 30. ...... 31. ...... 32. ...... 33. ...... 34. ...... 35. ...... 36. ...... 37. ...... 38. ...... 39. ...... 40. ...... 41. ...... 42. ...... 43. ...... 44. ...... 45. ...... 46. ...... 47. ...... 48. ...... 49. ...... 50. ......
The elements in a dry cell are ——(51) and ——(52). The electrolyte is ——(53).	51. ...... 52. ...... 53. ......
Polarization is prevented by ——(54) and ——(55). ——(56) closes the cell so the water cannot evaporate. Electromagnets are made by wrapping ——(57) wire on a ——(58) core. The strength of the electromagnet depends on the number of ——(59) of wire on the core.	54. ...... 55. ...... 56. ...... 57. ...... 58. ...... 59. ......
When a coil of ——(60) wire is turned in a ——(61) field a ——(62) is produced.	60. ...... 61. ...... 62. ......
This is a simple ——(63).	63. ......

All machines of this kind give an ——(64) current unless a ——(65) is used. 64. .... 65. ....
When cells are connected in parallel the ——(66) pole is connected to the ——(67) pole. 66. .... 67. ....
When the connection is made in series the ——(68) is connected to the ——(69). 68. .... 69. ....

When a ——(70) is sent thru a wire in a ——(71) field the wire moves. 70. .... 71. ....
This is a simple ——(72). 72. ....
Electricity is used to produce ——(73) and ——(74) or both. 73. .... 74. ....
Our homes are protected from over charges of electricity by ——(75). 75. ....

FOR THE BIOLOGISTS.

After A. L. Hodges from "Amazing Stories," May, 1930.

There lay the body. The man was known to have been subject to fits which would seize him and render him unconscious for sometimes two days at a time—but these were usual with him and he had been given many more years to live by the doctors. It was practically certain he had not died of one of these seizures. Then what had killed him?

He was found where he had fallen into a mass of tangled roots of the common pea, in a hole which had been recently dug. It was with some difficulty that they disentangled the vines, particularly from around his neck. Strangulation? Possibly, but these seizures were never known to cause the man to struggle when an attack came on—he simply dropped, unconscious.

As there was no mark on him, and no stones near for his head to hit, the cause had to be either the fit, or strangulation by cutting off his air supply.

The county farm agent commenced to study the mystery and finally came out with a most astonishing theory—he claimed that at that time of year pea vines grew very rapidly. He also claimed that not only did they grow rapidly, but that their strength was prodigious—that as they grew they could lift a 300-pound weight for every square inch exposed. He claimed that the heat of the man's body, along with a recent shower, and combined with the trophism of the roots to seek the ground again, caused them to crisscross over the man's throat, swell and strangle him while he was unconscious. This theory was finally accepted.

By A. L. HODGES.

555. The above is what we might call "Scientification." Is it harmful to the scientific spirit to read it? Remember, teachers, that the above is far more interesting than a discussion of the "growth of pea vines." What use can be made of the *Science* in "Amazing Stories" and other such magazines? (Read "The Ivy War" in the May, 1930, number of "Amazing Stories." Discuss it in class and let the Editor know the result.)

PUZZLING PULLEYS.

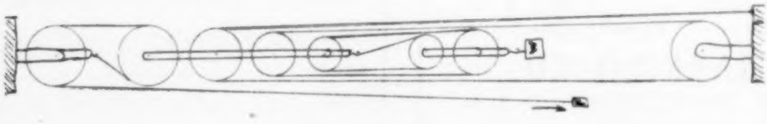
556. What is the Answer? *Proposed by Tom Martin, 46 Bay Street, City Island, New York City.*

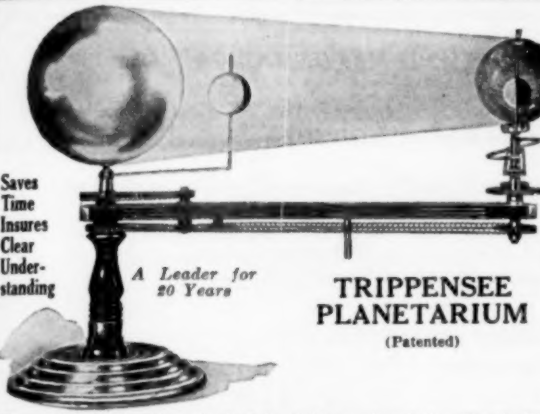
Enclosed you will find a drawing of a problem in pulleys which has been troubling me. By actual measurement I find that it has a mechanical advantage of 1 1-7 or 1.14, but I cannot seem to figure out why, from the pulleys. It seems to me that it should be 2.

I would appreciate it very much if you could help me out with this problem.

Yours truly,

Tom Martin.





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Write for Quotation

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557. *Proposed by Warren R. Lange, 731 Lincoln Ave., St. Paul, Minn.*

(1.) What is the cause of sun dogs (in detail please) (several suns seen on a clear cold day)?

(2.) Where is the attraction of gravity the greatest at the surface of the earth or the center? (in detail please)

(3.) The time of full moon to full moon is 29 1-2, and the actual time of revolution the moon around the earth is 27 1-3 day, please explain in detail, and by diagrams if necessary what this difference is due to.

AN ANSWER FROM IRELAND.

544. *Proposed by Dave Cervin, Rock Island, Ill.*

Dear Mr. Jones:

It is a long hail from Warrenpoint, Ireland, to the United States, but here goes for an answer to your monkey problem No. 544.

The smallest number of cocoanuts required to fulfill the conditions given is 3121.

A series of answers to the problem stated may be derived from the formula:

$$N = 15625x - 12504$$

where x may have any positive integral value commencing with 1.

A general solution to all problems of this type, (i. e. where there is no cocoanut over for the monkey in the final division), and for any number of sailors is obtained from:

$$N = n^{n+1} \cdot x - (n-1)\ (n^n+1).$$

where N is the number of cocoanuts, n is the number of sailors and x may have any positive integral value as before.

It is interesting to note that the corresponding general solution for the problem No. 532, solved by Hollister and others (i. e. where there is one cocoanut over for the monkey in the final division), is obtained from:—

$$N = n^{n+1} \cdot\ x - (n-1).$$

where the symbols stand for the same quantities, as in the previous case.

I enclose solutions to these two, which you may consider rather cumbersome, but if you care to propound these two cases as new problems, perhaps your readers may get some pleasure from solving them.

I find your little publication very useful and look forward to the American Mail which brings it.

Yours sincerely,

VINCENT CRAWFORD,

Cloughbeg, Warrenpoint, County Down, Ireland.

BOOKS RECEIVED.

Pharmaceutical Mathematics by Edward Spease, Professor of Pharmacy and Dean of the School of Pharmacy, Western Reserve University. First Edition. Cloth. Pages xii+126. 13.5x20.5 cm. 1930. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $1.75.

Laboratory Exercises in Zoology by William Morton Barrows, Professor of Zoology, The Ohio State University. Illustrated. Cloth. Pages vi+103. 13.5x20.5 cm. 1930. World Book Company, Yonkers-on-Hudson, New York. Price 84 cents.

Wonder Flights of Long Ago by Mary Elizabeth Barry and Paul R. Hanna of Lincoln School, Teachers College, Columbia University. Cloth. Pages vii+219. 12.5x19 cm. 1930. D. Appleton and Company, 35 West 32nd Street, New York. Price $1.00.

General Metal Work by Alfred B. Grayshon, Instructor in Metal Work, Jay Cooke Junior High School and Machine Shop Practice,

Frankford Evening High School, Philadelphia, Pa. Cloth. Pages viii+206. 15x23 cm. 1930. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York. Price $1.70.

Projective Pure Geometry by Thomas F. Holgate, Professor of Mathematics in Northwestern University. Cloth. Pages ix+286. 13x19.5 cm. 1930. The Macmillan Company, 60 Fifth Avenue, New York. Price $3.00.

Educational Biology by John C. Johnson, Professor of Biology and Head of Science Department, State Teachers' College, West Chester, Pennsylvania. Cloth. Pages xx+360. 13x20 cm. 1930. The Macmillan Company, 60 Fifth Avenue, New York. Price $3.00.

Ninth-Year Mathematics by Ernst R. Breslich, Associate Professor of the Teaching of Mathematics, The College of Education and Head of the Department of Mathematics, The University High School, The University of Chicago. Cloth. Pages ix+319. 12.5x19 cm. 1930. The Macmillan Company, 60 Fifth Avenue, New York. Price $1.20.

Laboratory Construction and Equipment of Chemical Laboratories. Cloth. Pages xiii+340. 15x23 cm. 1930. The Chemical Foundation, Inc., 654 Madison Avenue, New York.

A Study of Problem Material in High School Algebra by Jesse Jerome Powell, Instructor in Mathematics, The College of the City of New York. Cloth. 100 Pages. 15x23 cm. 1929. Bureau of Publications, Teachers College, Columbia University, New York City. Price $1.50.

Plane and Spherical Trigonometry by R. D. Carmichael, Professor of Mathematics, University of Illinois, and E. R. Smith, Professor of Mathematics, Iowa State College. Cloth. Pages x+198. 13.5x21 cm. 1930. Ginn and Company, 15 Ashburton Place, Boston. Price $1.60.

Analytic Geometry by David Raymond Curtiss and Elton James Moulton, Professors of Mathematics, Northwestern University. Cloth. Pages xiii+338+18. 13.5x20 cm. 1930. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $2.48.

Advanced Biology by Frank M. Wheat, Chairman, Department of Biology, George Washington High School, New York, Instructor in Biology, New York University, and Elizabeth T. Fitzpatrick, Chairman, Department of Health Education, George Washington High School, New York. Cloth. Pages viii+567. 13.5x20 cm. 1929. American Book Company, 330 East 22nd Street, Chicago, Ill. Price $1.80.

A Short History of Mathematics by Vera Sanford, School of Education, Western Reserve University. Cloth. Pages xii+402. 13.5x20 cm. 1930. Houghton Mifflin Company, 2 Park Street, Boston. Price $3.25.

Heroes of the Air by Chelsea Fraser, Author of "Heroes of the Wilds," "Heroes of the Sea," etc. Twenty-nine maps and forty-two photographs. Revised Edition. Pages xvi+562. Cloth. 13.5x19.5 cm. 1930. Thomas Y. Crowell Company, New York. Price $2.00.

Plane Trigonometry by Edwin S. Crawley and Henry B. Evans, University of Pennsylvania. Cloth. Pages v+177. 13x20.5 cm. 1930. F. S. Crofts and Company, New York. Price $1.65.

Tables of Logarithms edited by Edwin S. Crawley, Professor of Mathematics, University of Pennsylvania. Revised Edition. Cloth. Pages xxxvi+79. 13x20.5 cm. 1929. F. S. Crofts and Company, New York.

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COOPERATION WITH SECONDARY SCHOOLS BY THE COMMITTEE ON PLACE OF SCIENCE IN EDUCATION, OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The committee of the A. A. A. S. on the Place of Science in Education has announced a plan for cooperative work with secondary schools. A published statement of this plan appears in School and Society, March 22, 1930. Reprints of the published plan will be sent free to those desiring them if application is made to the Committee on Place of Science in Education, 433 West 123rd Street, New York City, N. Y.

The funds for carrying this plan into effect have been provided by a half dozen individuals who are keenly interested in the intellectual welfare of young people. The funds provided to the A. A. A. S. for this enterprise include $1800.00 which will be distributed to the libraries of those schools whose pupils are awarded "Recognitions of Merit," and the books thus purchased will be presented to the libraries in the names of those pupils. These pupils also receive other important recognitions which are described in the full report. Pupils may work singly or in groups. Source materials are advised from several departments of the school program. A wide range of topics for work is suggested, from which selection may be made.

Several types of published results may come from the enterprise, and in these publications it is hoped that pupils, teachers and librarians may all have a part. The whole plan is designed to provide worthy and useful opportunity for creative work by individuals and groups who possess capacity and interest for superior achievement in study and in writing.

After this plan had been authorized by the Council of the A. A. A. S., it was suggested by an experienced officer of the National Education Association that copies of the full plan be sent to twenty-five outstanding school superintendents and high school principals, with request for their opinions of its possible usefulness. At the time of writing this announcement, eighteen of the twenty-five have replied. Some of these raise important questions as to the ways in which the plan will work, but all express approval and some make important suggestions for improvement, which suggestions have been incorporated in the plan.

Excerpts from these replies are presented as showing the various types of reactions.

1. The assistant superintendent in charge of high schools in a city of over a million inhabitants says:

"I have read the plan several times and it seems to me to be excellent. The purpose is most worthwhile and I believe that the plans for accomplishing the purpose will work."

2. A superintendent in an eastern city of twenty-five thousand inhabitants says:

"I have read carefully the letter and plan enclosed and am very forcibly impressed with the educational value of the plan. Often high school pupils will demonstrate surprising ability in writing. I believe the plan you propose will be a means by which some of this latent ability will be discovered. It should also inspire a greater interest and a spirit of research in many high school pupils. A third possibility is the inspiration to better teaching of science in the high schools participating in this plan, since the teachers of science in

such schools will have brought to their attention the possibilities of important authorship by their students, and the necessity for careful and authentic gathering and analyzing of facts. A fourth effect, it seems to me, would be the emphasizing of the importance of science as a high school study, as a result of a clearer conception of its importance in daily life."

3. The principal of a large New York City high school makes an extended comment all of which is significant:

'Since the publication, in 1928, in the Bulletin of High Points, of Superintendent Tildsley's report on Science as a Way of Life, the Department of English in this school has been especially interested in the study of the lives of men of science as well as in the use of prose for scientific exposition. As a matter of fact, the department is, at this present moment, engaged in the project of making an anthology of essays on scientific subjects for use in eighth term classes in literature. This anthology is designed to take the place of such texts as Washington's Farewell Address and Burke's Speech on Conciliation, which in the opinion of the Department of English, failed to produce ability in the pupil to deal with problems involving abstract ideas and the technique of scientific procedure—problems which are of paramount importance in our life today. I may say, therefore, that your plan is in line with the work now being attempted in the eighth term of the course in literature. I am, therefore, glad to promise the cooperation of the Department of English. You may know, also, of the new course in European history which is now being constructed and evaluated in the city high schools. This course involves a survey of scientific progress in the fifteen units of historical study. I can, therefore, promise you also the help of our teachers of history. The plan, then, as outlined in your circular, is of interest to us. It is a plan to which I gladly lend my approval.

"The results of a competition such as is described in your pamphlet cannot be predicted, but it seems fair to expect that the importance of the scientific attitude of mind may be given an additional emphasis by work like this and that knowledge of the bibliography of the various sciences may thereby be spread.

"As I said in paragraph (1), I should be glad to be counted among those principals who wish to approve the competition in their schools. Of course, from secondary school students we can expect a small proportion only of work of superior quality. However, the project should result in a wider dissemination of valid ideas on scientific subjects."

4. A principal of a high school of two thousand pupils says:

"I personally like the idea very much. I can think of outstanding students of science in our school in the past who would have produced something well worth reading along this line. Such outstanding students in science may not be present in our school every term, but over a period of terms I am sure that at least three terms out of four we should find students who would profit very much by taking part in the plan you outline.

5. The principal of a large senior high school analyzes his ideas as follows:

"Outstanding merits of the plan:

1. Offers originality of self-expression through language of very objective matter.
2. The provision for the school receiving the material reward in

the form of library books, thus emphasizing work for and loyalty to an institution.

3. Offers more cooperation between Science and English and possibly also Social Sciences in a definite school project.
4. Encourages pursuit of higher education through possible scholarship honor.

Weakness of plan.

1. The possibility that prize winning topics in any one year, will not correlate for use as a reference in the libraries of the cooperating schools.
2. It is apt to become like all prize contests a competitive drive on the part of faculty against faculty rather than students against students.

"Our science teachers are much interested, and will consider using it when published."

Correspondence from secondary school principals and teachers is invited. Address, Committee of the A. A. A. S., on Place of Science in Education, 433 West 123rd Street, New York City, N. Y.

BOOK REVIEWS.

Botany, Principles and Problems, by Edmund W. Sinnott, Professor of Botany, Barnard College, Columbia University. xix+441 pp., 269 figures. 5¾ in.x9 in. McGraw-Hill Book Company, Inc., 370 Seventh Ave., New York. Second Edition, 1929. $3.00.

The First Edition of this book which appeared in 1923 was an excellent botany text book. The Second Edition has been improved in various ways and brought up to date. Approximately two-thirds of the text is devoted to morphology and physiology of the seed plant as a living organism, and a third of the book is used in treating the plant groups in evolutionary sequence. Two outstanding features of the book are scientific accuracy and pedagogical organization and treatment of materials. At the end of each chapter there is a set of Questions for Thought and Discussion, and a set of Reference Problems. The total number of the former in the book is 474, and of the latter, 238. Other books have questions, but this one is unique in the type of questions. Followed as intended, the text goes a long way from the matter of fact, memorization type of teaching. The straight lecture method and quiz on facts may be easier to apply, but the occasional use of questions, such as Sinnott gives, with any method will compel a resort to reasoning based on a knowledge of principles. As an example of the use of definite clear cut language used throughout the book, the discussion of the subject of diffusion and osmosis is a classic. The writer of this review knows of no better text for use in an elementary course in college botany.

Jerome Isenbarger.

A Biology Workbook, by James C. Adell, Chairman of the Biology Division, Lincoln High School, Orra Olive Dunham, Chairman of the Biology Division Collinwood High School, and Louis E. Welton, Head of the Science Department, John Hay High School, all of Cleveland, Ohio. vi plus 325 pp. 7¾ in.x10½ in. 111 figures. Ginn and Company, 15 Ashburton Place, Boston. $1.32. 1929.

This laboratory and study guide in elementary biology contains much more work than could be finished by any ninth or tenth grade class in a school year. The great mass of material which it furnishes makes it possible to select that which is most suited to the conditions under which the class is working. It also makes it possible to require a minimum of work of the average pupil and assign extra work to be done by those capable of doing more.

The plan of the book may be illustrated by a description of "Unit II", The Building Blocks of Living Matter. Three experiments are suggested which are studies of cells as seen in onion skin, in pond scum or Elodea, and in hay infusion. Drawings are provided which are to be labeled by the pupil. 29 questions are provided at the end of the exercise which call for reading of references and class discussions. A complete list of references is given. A list of 18 words is added for spelling and use. Some of the so-called units could not be considered as complying with the Morrisonian requirement that a unit in science is some significant and comprehensive part or aspect of the environment or of the science. "Unit I", "What is There of Interest in Flowers and Insects?" may be cited as an example. "Unit VII", "Fads and Facts about Gaining and Reducing," is another example. A highly commendable feature of the workbook, prominent throughout, is that it is a guide to a study of biological principles, using plants and animals as living things to illustrate,—not unrelated studies of plants and animals.

Jerome Isenbarger.

Agricultural Mathematics by L. C. Plant, Professor of Mathematics, Michigan State College. Cloth. Pages lx+199. 19.5x12.5 cm. 1930. McGraw-Hill Book Company, Inc., New York. Price $2.50.

This book presents a collection of the mathematics materials needed by students who are taking courses in agriculture. In addition to such topics as equations, graphing data, indices and radicals, logarithms, simultaneous equations, etc., with which the student must be familiar if he is to attack successfully many of the problems arising in agriculture, are included chapters dealing with probability, the applications of probability to problems in heredity, and statistics. Probability is included because it is necessary for a comprehensive understanding of certain agricultural subjects, while statistics is included because the student in reading agricultural reports is constantly encountering averages which have the probable error attached.

The organization of the book follows the laboratory plan. Thus students can work through the material by merely following the directions of the author. A large number of applied problems are provided, and their difficulty is so varied that the needs of all types of students are provided for.

The book should find favor with teachers of mathematics in agricultural schools and with those teachers of mathematics who are constantly searching for practical problems.

C. A. Stone.

At Home among the Atoms. (A First Volume of Candid Chemistry.) James Kendall, A.M., Sc.D., F.R.S. Professor of Chemistry and Dean of the Graduate School, New York University. Professor-Elect of Chemistry, University of Edinburgh. The Century Co. 1929. xvi+318 pp. 21 illustrations. 12x20 cm. $3.00.

One is at a loss how to classify this book. Its order of topics is much as that of a college textbook, but its style—well, it reads like a humorous story book. Yet even a chemist would hardly recognize textbook promise in such chapter headings as: Valencia, Gentlemen Prefer Blondes, Pep and Popularity, The Apartment House; Rewriting the Constitution, or Moving into the Country. Nor would a non-technical reader get much humor out of "diffraction gratings," "co-valence and non-polar compounds", "losing mass and gaining energy", "quanta", and "classical dynamics." The author himself admits "Some chapters are really serious."

Yet when the chapter titles are translated there is the time honored textbook sequence of: Matter, its classification, its changes, atoms, atomic weights, symbolism, oxygen, crystals and atoms, hydrogen,

valence, chlorine and other halogens, energy in chemistry, the periodic classification, the alkali and alkaline earth metals, atomic structure and aluminum as well as the Lewis and Langmuir atom, the Bohr atom and the Schrödinger atom. The lay reader can readily appreciate such allusions as: "Oxygen, the Lizzie of the elements because it is so abundant", "hydrogen growing up and going to work even though rather lazy", "chlorine with a reputation that never has been spotless", "Scheele as the greatest chemist who ever kept a drugstore", "the old Tories of the London Chemical Society enjoying a perfectly topping time over Newland's paper on 'The Law of Octaves,' the atom as not what it is cracked up to be—one indivisible, indestructible, eternal and so on."

Many teachers acknowledge that the vocabulary of chemistry has a provoking habit of getting in the way of student understanding. Some readers of this book may lament that analogies lack precision, yet there are others who will agree that if "the idea is the thing" then let the idea be exalted even tho it be necessary to stoop to lowly levels of English usage in the act.

Not since the publication of the one time famous Steele's "Fourteen Weeks" series has the reviewer found such affective use made of anecdotal biography. In brief but spicy and well turned phrases, pertinent stories in the lives of the master pioneers of chemistry are used to humanize the matter as it is presented. True, the names used are very well known to chemists, but, of more moment, to the non-technical reader they will hereafter be *favorably* known.

There are places in this "candid Chemistry" where the author has, perhaps, gone a bit too far in his informality, as when he asks "Caloline to powder the wick of her cigarette lighter" or when he calls hydrogen a "Nize baby." But enough teachers have sinned so shamelessly at the other extreme that compensation is achieved.

In brief, here is a book that each teacher of chemistry will want upon his *laboratory* book shelf, placed there that faster working, clearer thinking students may be intrigued into a perusal of some of the more subtle yet, to him, more challenging phases of chemistry.

B. Clifford Hendricks.

General Metal Work, by Alfred B. Grayson, Instructor in Metal Work, Jay Cooke Junior High School and Machine Shop Practice, Frankford Evening High School, Philadelphia, Pa. Cloth. Pages viii+206. 15x23 cm. 1930. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York. Price $1.70.

This book was designed to cover the metal shop work in the junior high school. The opening chapter is devoted to the study of the various kinds of metals which are most common in beginning shop work and to the tools, solders and various seams. The next four chapters describe the various kinds of work, such as (1) vise work, which includes instruction in the use of the chisel, saw, hammer, files and squares; (2) drilling, the construction of the drill press, kinds of drills, punches, and reamers; (3) taps and dies; (4) the lathe and lathe tools. Included under the title "lathe work" are the topics of construction, care, and use of the lathe. As the various uses of the lathe are taken up the tools necessary for the different operations are described together with their construction, care, and use. Each one of these chapters is concluded with a set of questions which the student will be likely to encounter in his work, and with a list of references to the subjects discussed in the chapter.

The second part of the book contains projects with operation sheets. These projects start with the simple, fundamental operations and advance to the more difficult, each involving a new problem. The "directions" are divided into material, operations, remarks, and questions, together with mechanical drawings of the project. The author has tried to make these problems of such nature that they will interest the pupil as well as being useful and practical to him.

The third part of this book contains useful shop data and tables and many practical recipes and compositions.

L. C. W.

A Source Book in Mathematics, by David Eugene Smith, Ph.D., LLD., Professor Emeritus in Teachers College, Columbia University. pp. xvii+701. 16x23. 5 cm. 1929. McGraw-Hill Book Co., Inc., 370 Seventh Avenue, New York.

This book brings together a large amount of source material in mathematics which covers a period of four and a half centuries extending from the advent of printing to the year 1900. The attempt has been made to include excerpts from the writings of the masters that are basic in the various fields of mathematics.

These excerpts, of which there are ninety-six, are placed in five classes, viz.: I The Field of Number; II The Field of Algebra; III The Field of Geometry; IV The Field of Probability; V The Field of Calculus, Functions, Quaternions.

For the preparation of this volume the mathematical public is indebted to the gratuitous services of Professor Smith, an advisory committee consisting of Professors Archibald, Cajori, and Dickson, and to a large number of people who have assisted in editing and translating the excerpts.

This book should be found in the library of every teacher of mathematics, and in the libraries of high schools and colleges.

J. M.Kinney.

A Guide for the Study of Plants, by Mabel E. Smallwood of the Department of Biology, Lane Technical High School, Chicago. vi plus 97 pp. D. C. Heath and Company, 1815 Prairie Ave., Chicago., 1929.

This is a laboratory manual covering a year of high school botany. It is arranged according to seasonal sequence so that materials will be available for the work of the fall semester and for that of the spring semester. The work of the fall semester begins with a study of weeds and fall flowers, seeds, fruits, and the adaptation of plants for winter. The greater part of the semester is devoted to studies of the plant groups. The work of the spring semester begins with a study of the condition of plants during the winter, seeds and seedlings, food and food material. The greater part of the spring semester is devoted to a study of the structure and work of seed plants. The general plan of the exercise depends on the nature of material, however a typical exercise may be described, as Study of Stems: To Show Uses and Structures of Stems. The study is divided into general external structure and internal structure. Under the former, first there is a general statement of plan of study. Then follows definitions of terms used, a list of questions on the laboratory and field materials, and a summary of the study of general character of stems. The same general plan is followed in the study of the internal structure. Then follows a list of five experiments on stems, and a set of twenty-five questions for review and library work on stems. While the work is given in definite sequence, the arrangement may be varied to suit local conditions. The directions are clear-cut and definite, the exercises are practical, and the manual as a whole is decidely usable.

Jerome Isenbarger.

Elementary Science by Grades.

This is the title of a series of science readers by Ellis C. Persing, Chairman of the Department of Science in the School of Education, Western University and Elizabeth K. Peeples, Principal in the Washington, D. C., Public Schools, and published by D. Appleton and Company. Many teachers of the elementary grades recognize the

need for science readers and will give a hearty welcome to this series. Book One, especially prepared for the little folk, is exceptionally attractive in appearance and contains good subject matter well arranged. The vocabulary is carefully selected. Children will not only like this book, but, by reading it, they will see and enjoy many things in the world about them—animals, birds, trees, flowers, machinery, the stars, and the weather become interesting subjects of study and observation.

G. W. W.

PUBLICATIONS ON ATTRACTING BIRDS.

Department of Agriculture Publications.

How to Attract Birds in the Northeastern United States, Farmers' Bulletin 621, price 5c.

How to Attract Birds in the Northwestern United States, Farmers' Bulletin 760, price 5c.

How to Attract Birds in the Middle Atlantic States, Farmers' Bulletin 844, price 5c.

How to Attract Birds in the East Central States, Farmers' Bulletin 912, price 5c.

Community Bird Refuges, Farmers' Bulletin 1239, price 5c.

Homes for Birds, Farmers' Bulletin 1456, price 5c.

Eleven Important Wild-Duck Foods, Department Bulletin 205, price 5c.

Propagation of Wild-Duck Foods, Department Bulletin 465, price 10c.

Gourds for Bird Houses and Other Purposes, Leaflet 36, price 5c.

A supply of the above publications is available for free distribution, but when it is exhausted copies may be had at the prices given, upon application to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Publications of Audubon Societies.

Bowdish, B. S. Putting Up Bird Boxes: How to Make and Where to Place Them. Special Leaflet 18.

Hiesemann, Martin. How to Attract and Protect Wild Birds.

Kennard, F. H. A List of Trees, Shrubs, Vines and Herbaceous Plants, Native to New England, Bearing Fruit or Seeds Attractive to Birds.

Job, H. K. Attracting Birds About the Home. The Propagation of Wild Birds: A Manual of Applied Ornithology.

All the above may be obtained from the National Association of Audubon Societies, 1974 Broadway, New York, N. Y.